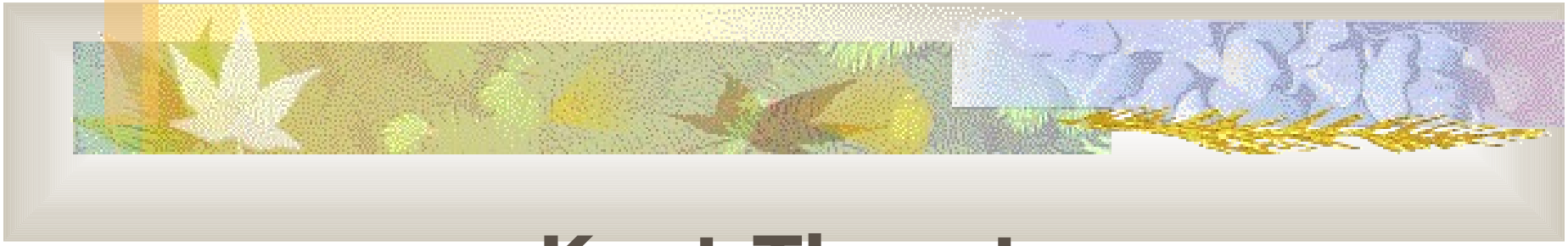
# Workshop on Ecosystem Modeling and Restoration:

# Time, Space, and Integrated DSS



Kent Thornton

FTN Associates

# Workshop Agenda

- Workshop Summary
- Integrated Process
- Bounding the Problem
- Selecting Tools
- Solving the Problem
- Resolving the Issue
- Open Discussion Forum (Afternoon)

# SWWRP Workshop June 2006

- Challenges in Ecosystem Modeling and Decision-Making:

  **District and Division Needs**

- Listening Workshop
  - **Managing and Restoring Aquatic Ecosystems**
  - **Decision Support Systems Tools**

# District and Division Needs

- Upper MS River Restoration
- Minnesota River Restoration
- Everglades Restoration
- Puget Sound Improvement
- Navigation Pool Enhancement
- Wetland Creation, Restoration
- Beach Nourishment
- Shoreline Protection

# District and Division Needs

- GOM Coastal Restoration
- Chesapeake Bay Restoration
- Urban Stream Restoration
- Selective Withdrawal Design
- Island Creation
- Fish Passage Structures

# Desired Outcomes

- Ecosystem Services Restored
- Floodplain Restoration
- Wet Prairie Restoration
- Endangered Species Habitat
- Invasive Species Eradication/Mgt
- “Natural” Down-stream Flow Regime

# Desired Outcomes

- Stormwater Management
- Beach Nourishment
- Mine land Reclamation
- Urban stream ecosystems

# Temporal – Spatial Interests

- Time
  - Hour
  - Day
  - Season
  - Annual
  - Decadal
  - Century
- Space
  - Meter
  - Hectare
  - Watershed
  - Estuary
  - Basin

# Tools

- HEC-RAS
- HEC 6
- FLO2D
- CE-QUAL-W2
- ICM
- IBI
- HIS
- HGM . . .
- HEAT
- GSSA
- HSPF
- CE-QUAL-RIV
- SIAM
- HEP/mHEP
- SAM
- URGWOM . . .

# Tool (Modeling) Wish List

- User Friendly Desktop Interface
- Scalable Eco Models (Reach to Basin)
- Realistic Field Data Requirement
- Interactive Benefit Impact Display
- Easily Communicated Output
- Linkable/Inter-active Models
- Auto-tracking Changes and Updates
- GIS Interactive Models
- Quan/Qual Habitat Valuation
- On-the-fly Design Alt.

# Additional Everglades Tools

- Enhanced Hydrol. Models
- Vegetation Succession Models
- Biotic species -Community Model
- Restoration Optimization
- Landscape WQ Models
- Soil/Sediment Transport/Process Models
- Landscape Evolution Model
- ET Tool

# Decision-Making

- Multi-Criteria Decision Analysis
  - Ultimate Objective – Inject Science into the Decision-Making Process
  - MCDA Structured Process for Decision-Making
    - Trade-off Analyses
    - Benefit – Cost – Risk
    - Certainties – Uncertainties

# Upper MS River DSS Framework

Figure 1. Upper Mississippi River DSS framework.

# General DSS Framework

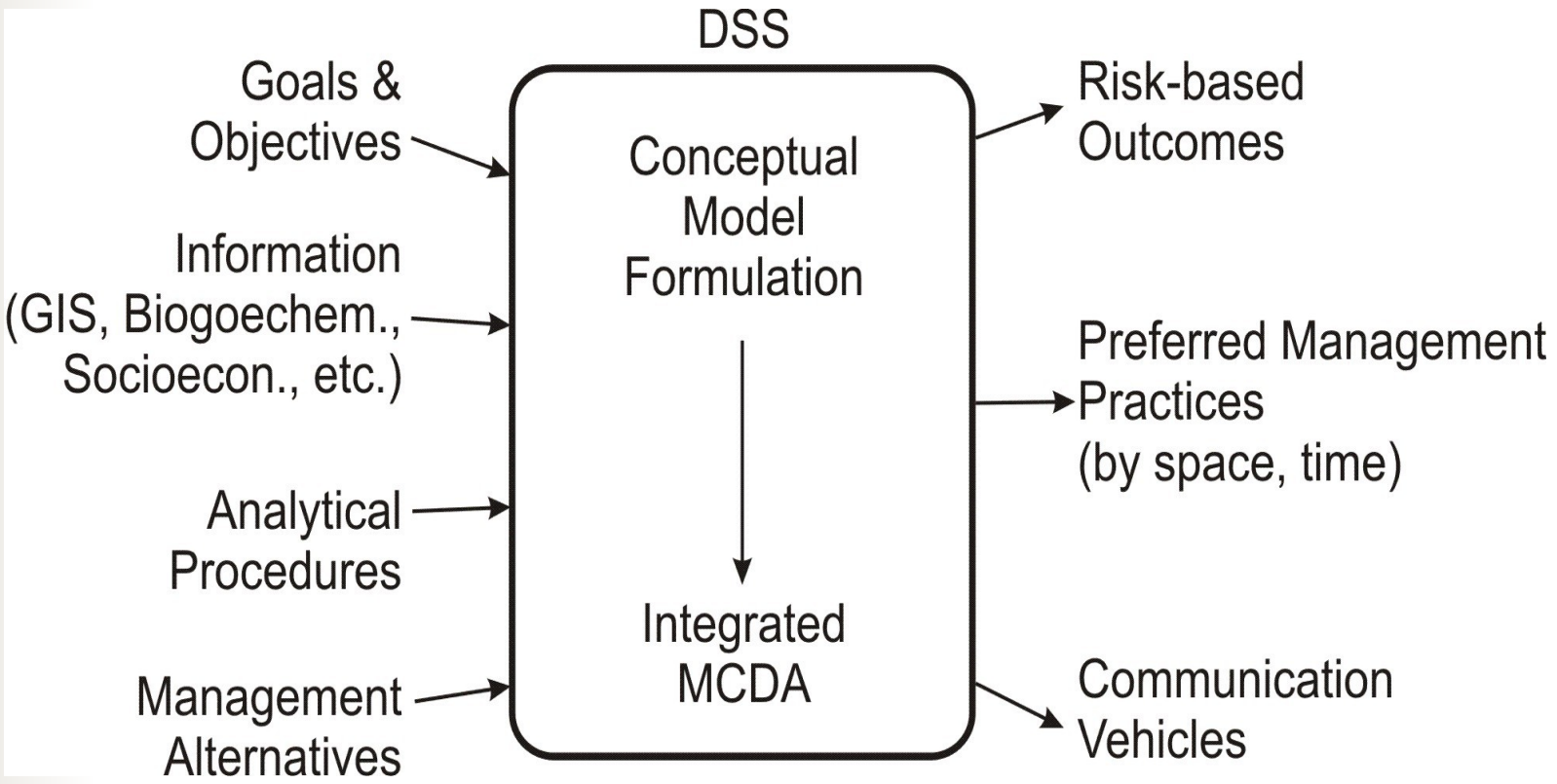



Figure 2. Possible DSS framework for SWWRP.

# Questions ?

# Discussion

# Integrated Process

## Ecosystem Modeling, Restoration, and Decision-Making

# Bottom Line

- **It's the Whole;**
  **Not the Parts**
- **It's the Process;**
  **Not the Product**
- **It's the Issue;**
  **Not the Problem**

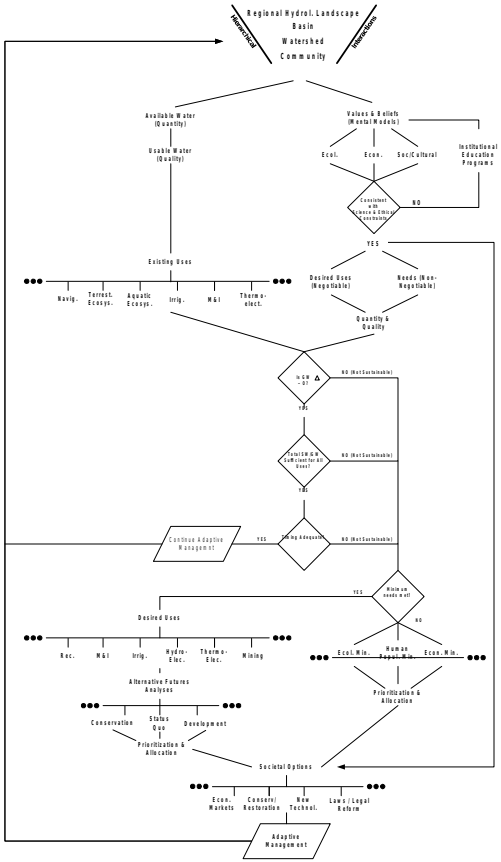
# SWWRP Goals

- **Provide the Corps and its Partners with the Capabilities to:**
  - **Balance Resource Development with Ecosystem Requirements**
  - **Restore & Manage Water Resources Over Multiple Time/Space Scales**
  - **Achieve Environmental Sustainability**

# SWWRP Goals

- **SWWRP Will Achieve Goals By Developing DSS to:**
  - **Transition From Site-Specific to Holistic, Integrated Assessment and Management**
  - **Apply Current/Improved Methods for Forecasting System-wide Mgt Outcomes**
  - **Permit Alternative Evaluation, Trade-off Analysis and Decision Support Across Watershed and Basins**

# Solving Engineering Problems



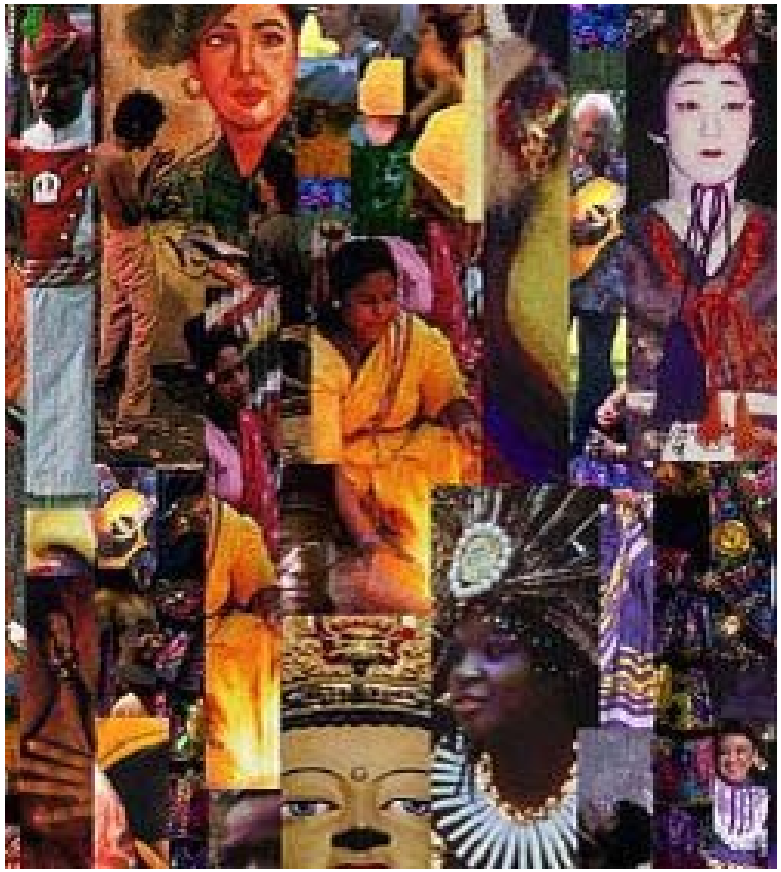

- Problem Identification
- Scoping
- Design
- Build
- Operate
- Next Problem

# Engineering Problem => Environmental Management

- Problem or Issue?
  - Problems have *Solutions*
    - Engineers
    - Natural Scientists
  - Issues have *Resolutions*
    - Engineers, Natural Scientists
    - Socioeconomists
    - Politicians
    - And Others

# Social/Cultural

- Beliefs & Values
- Truth/Perception
- Mental Models
  - Individual
  - Community
- Modeling Philosophy
- Problem Solving Process



# Guiding Principle

- **Principle 1: Humans are part of, not apart from, aquatic ecosystems and their watersheds.**
- **Principle 2: Water Is THE Integrator – Essential for Life**

# Lessons Learned

- Numerous Interdisciplinary Projects
  - Signature Programs/Projects
    - EWQOS
    - NAPAP
    - EMAP
    - South Florida Ecosystem Assessment
    - Water and Watersheds
    - Mid-Atlantic Integrated Assessment
    - EaGLe Atlantic Slope Program
    - WERF Sustainable Water Resources Management

# Lessons Learned (Con't)

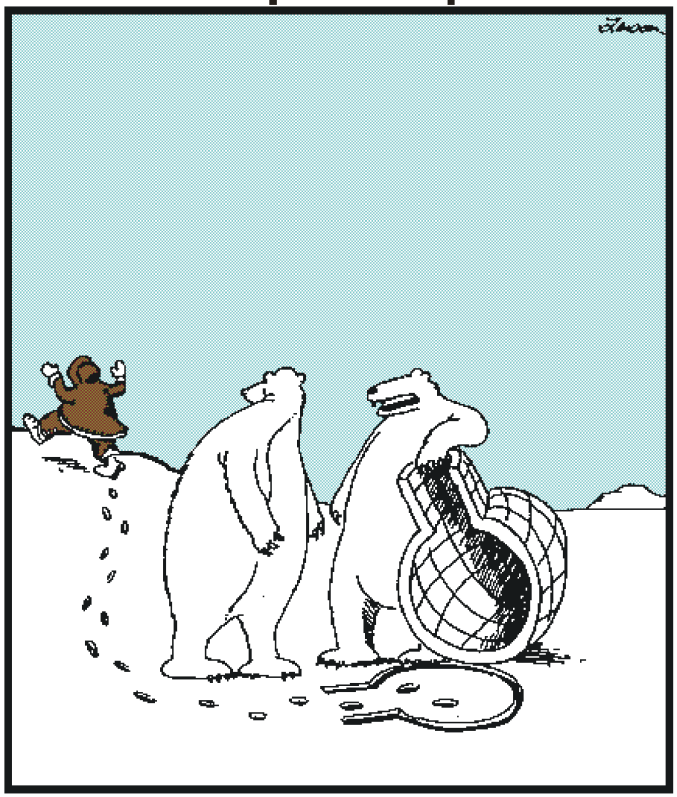
- Start With The End In Mind
  - Achieve Desired Outcomes
  - Make Decisions
    - NAPAP – Acid Rain Problem vs Acid Rain Issue
    - Factors
      - Engineering and Scientific Findings
      - Socioeconomics
      - Politics

# Lessons Learned (Con't)

## Process

- Use a Suite of Methods (Tools)
- Start with the Simple Methods (Tools)
- Keep It As Simple As Possible, But No Simpler (Einstein)
- It's Data Driven (Smith et al., 2003)

Keep It Simple



"I lift, you grab. ... Was that concept just a little too complex, Carl?

# Lessons Learned (Con't)

- Modeling Principles
  - **All Models Are Wrong; But Many Models Are Useful (Box)**

  Corollary:
  - **All Models are Imperfect; But Many Imperfect Models Add Weight of Evidence**
  - **All Model Predictions are Relative: But Relative Changes Are Useful.**

# Implications

- Decision Support Systems
  - Consider the Lessons Learned
  - Consider An Integrated Process
  - No Magic Bullet; No Perfect Tool
  - Weight of Evidence Approach
  - Contribute To Decision-Making
  - Solve Problems and Resolve Issues

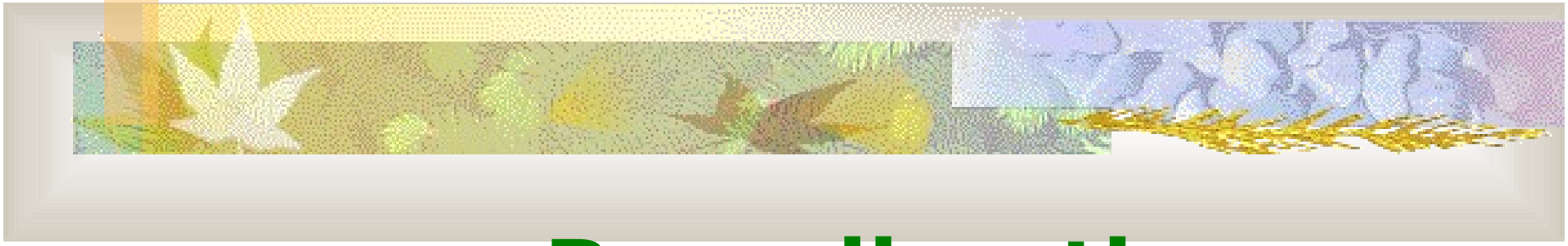
# Integrated Process

- Bounding the Problem
- Selecting the Tools
- Solving the Problem
- Resolving the Issue

# Questions ?

# Discussion

# Integrated Process



## Bounding the Problem

# Messages

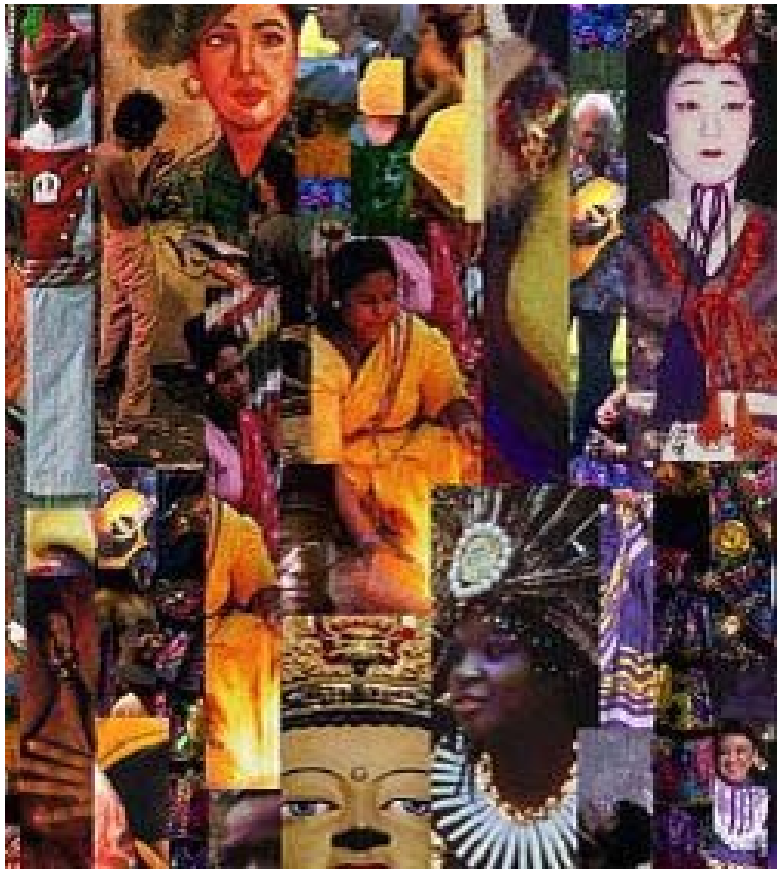
- Begin With The End in Mind
- Make Sure You Know THE Questions
- Make It Relevant To Management

# Desired Outcomes

- Ecosystem Services Restored
- Floodplain Restoration
- Ecosystem Sustainability
- Endangered Species Habitat
- Invasive Species Eradication/Mgt
- “Natural Down-stream Flow Regime
- Native Prairie Restoration

# Social/Cultural

- Management Is Fundamentally A Social Activity
- Economics Part of Solution
- Consider Socio-Economic Endpt Relationships to Management – Ecol. Indicators



# Endpoints

## Management Endpts

- Navigation
- Eco. Sustain.
- Drinking Water
- Flood Control
- Aquatic Life Use
- Wetland Creation
- Estuarine Cond.

## Ecol. Indicators

- Fish/Benthos
- Food webs
- ac-ft, Chl a
- Channel Depth
- IBI
- Acreage, WBI
- Sea grass Extent

# Relevant Eco. Assess. Endpts

- Organism
- Population
- Special Places
- Community or Ecosystem

**Eco. Assess. Endpts for Great Rivers EMAP 2005**

- Mussels, Snails, Mammals, T&E Birds, Fishes, Rec. Waterfowl, Reptiles, Amphibians, Insects
- UMR Driftless Area
- Backwater, Oxbows, Wetlands, Fish Communities

# Questions

- Ask The Right Questions:
  - Solving the wrong problem
  - Stating in-answerable questions
  - Solving a solution
  - Questions too generic
  - Agreement on answer before questions (Bardwell 1991)

# Bounding the Problem

- Ecological Indicators
- Time and Space
- Conceptual Models
- Order of Magnitude Estimates
- Empirical Models

# ASC Management Implications

- Managers Want Suites of Tools & Indicators
- Use Depends on:
  - Question Being Asked
  - Time and Space Scale for Answer
  - Context or Social Choice
- Taxonomy of Indicators

## What's your type of question (indicator)?

- Condition Assessment
- Evaluate Performance
- Diagnose Stress./Pressure
- Communication w/ Public
- Futures Forecast/Restore

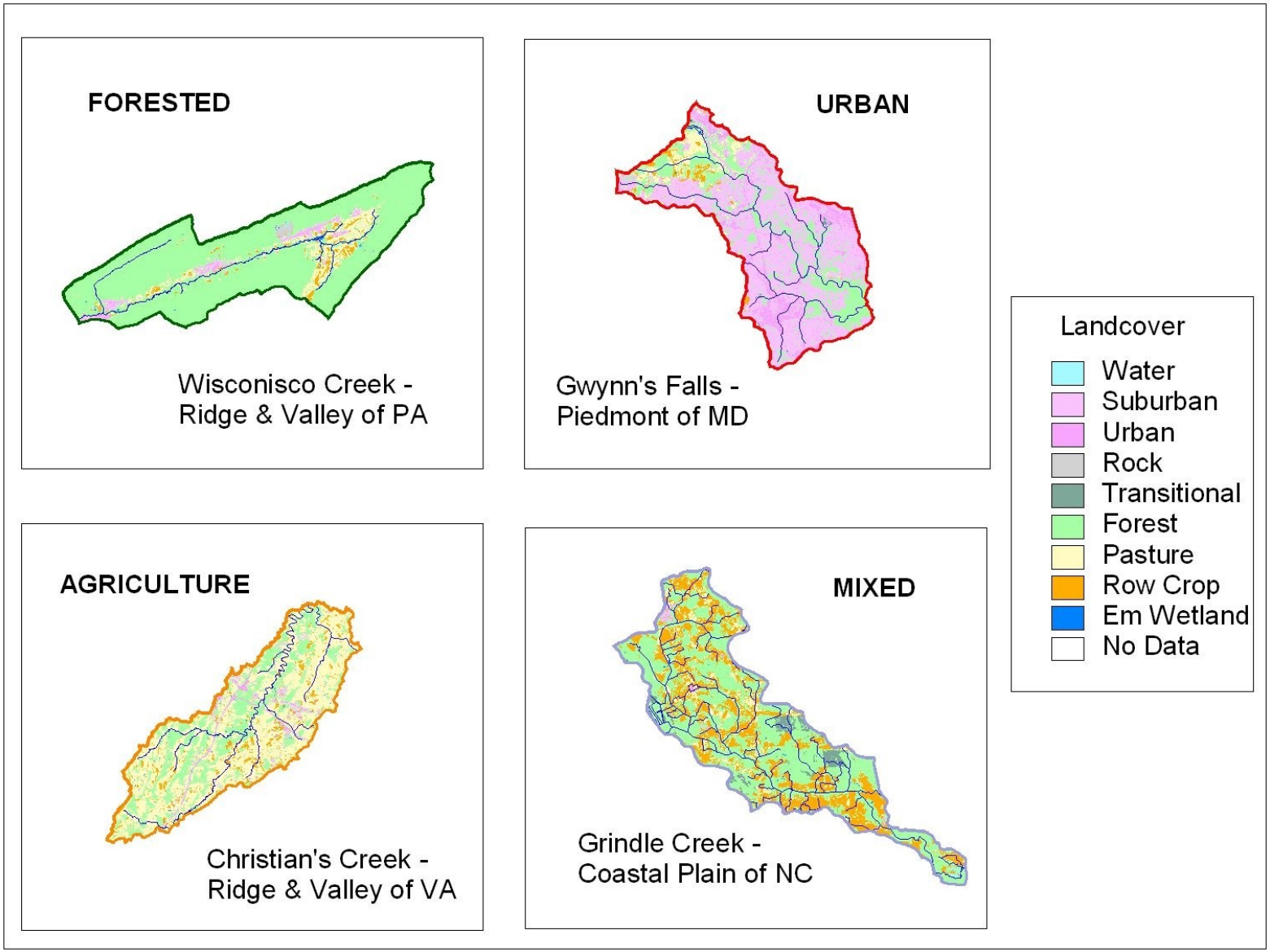
## What's your spatial/temporal scale of interest?

| Site | Reach | Small Watershed/ 14-digit HUC | County | Large River |
|---|---|---|---|---|
| Days | Months | Seasons | Years | Decades |

## What's the context (i.e., social choice)?

- High Slope Forested
- Low Slope Forested
- Agricultural
- Urban
- Mixed/High Variance
- Mixed/Low Variance

# Social Choice = Land Use Pa

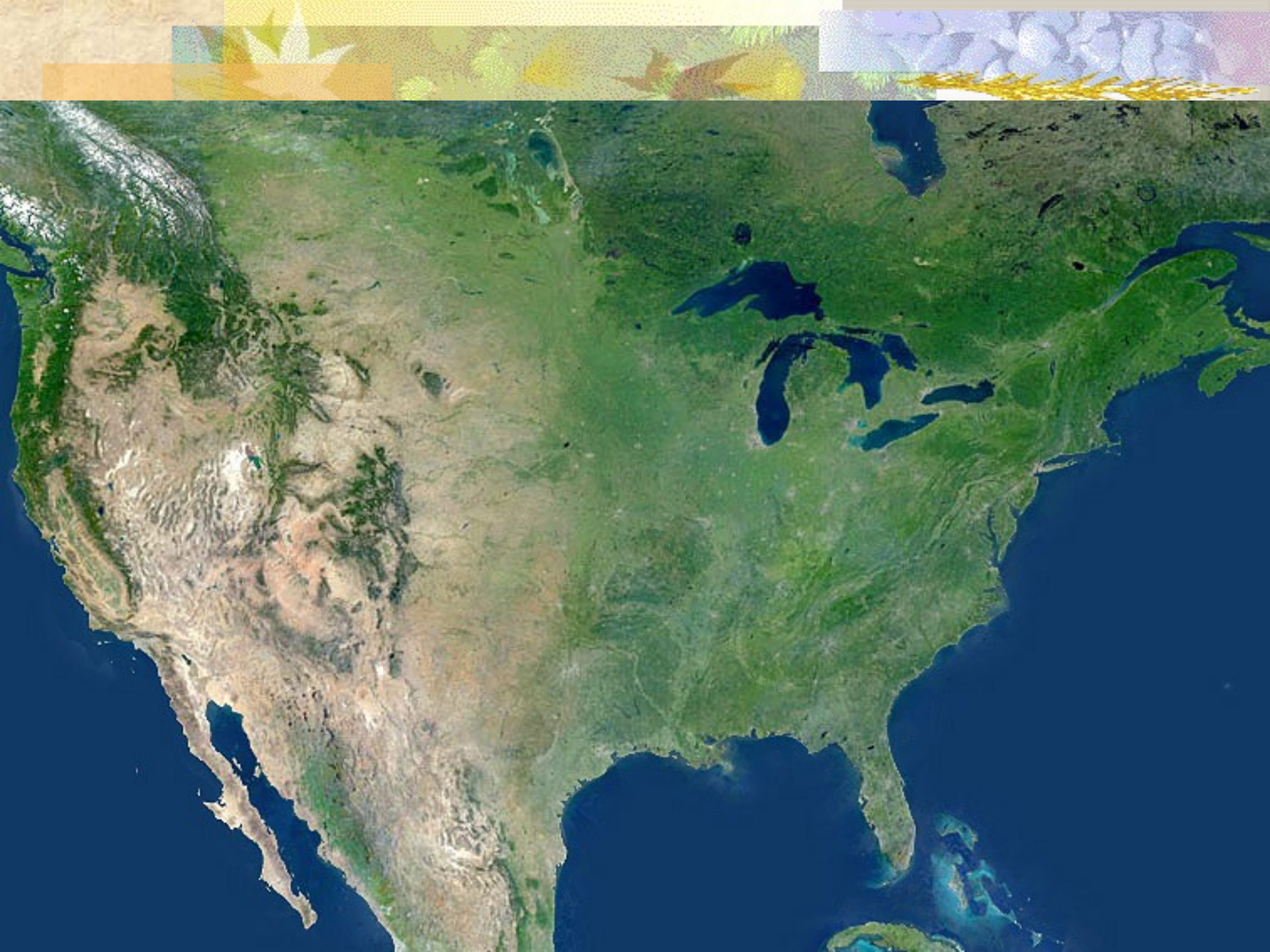


# Indicator Taxonomy

| Indicator | Ques. | Time | Space | Context |
|---|---|---|---|---|
| IMBCI | Cond., Diag. Comm. | Yr-Decade | Marsh-Est. Segm | Emergent Marsh |
| B-IBI | Cond., Diag. Comm. | Decade-Year | Site-Sm. WS | L-S Forest Agriculture |
| S-WRI | Cond., Diag. Comm. | Season-Year | Reach-Sm. WS | Ag., Urban, Mixed |
| SBS | Cond., Diagn. | Season-Year | Reach | Ag., Urban, Mixed |
| Inverse Dist. Wt. Develop | Cond., Diag | Season-Decade | Reach-WS | Urban, Mixed |

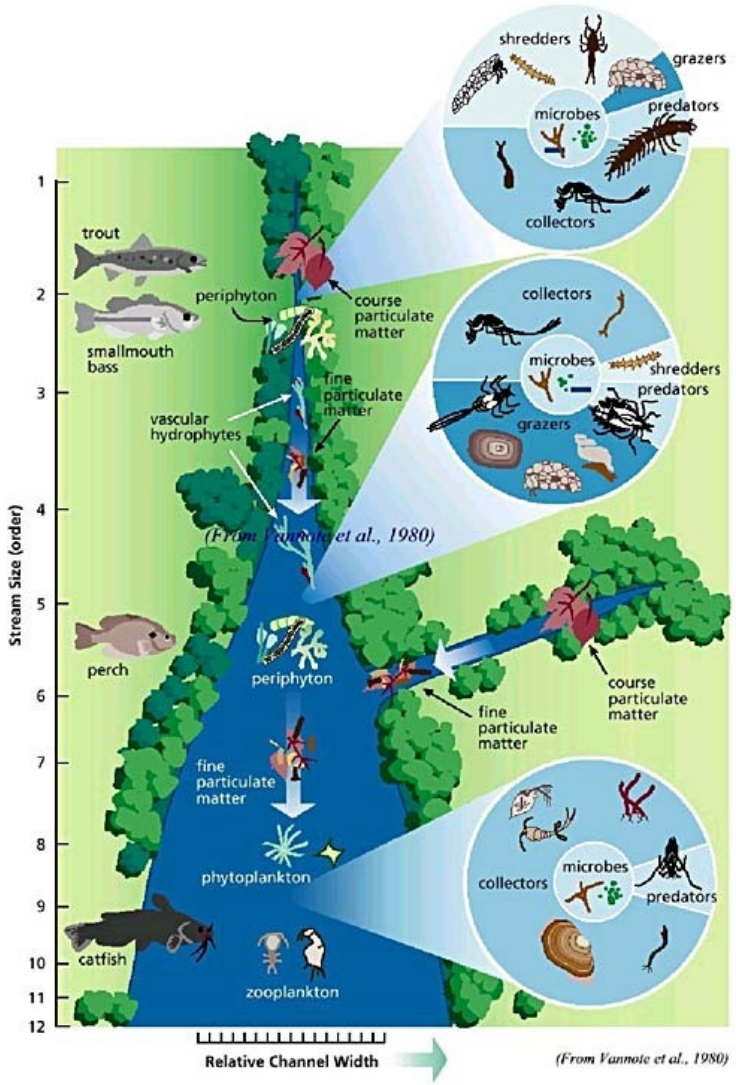
# Global Scale

- Hydrologic Cycle Closed Globally
- Holistic
- Continuous Regimes
  - Aquatic
  - Atmospheric
  - Terrestrial
- What Are Time and Space Scales?



# River Continuu

- River Continuum Concept
- Seamless Gradients
- Different Processes Dominate



# Hierarchy Theory

Level +2 ~ Constant

Level +1 ~ Slowly Varying

Level +0 ~ Management Endpoint

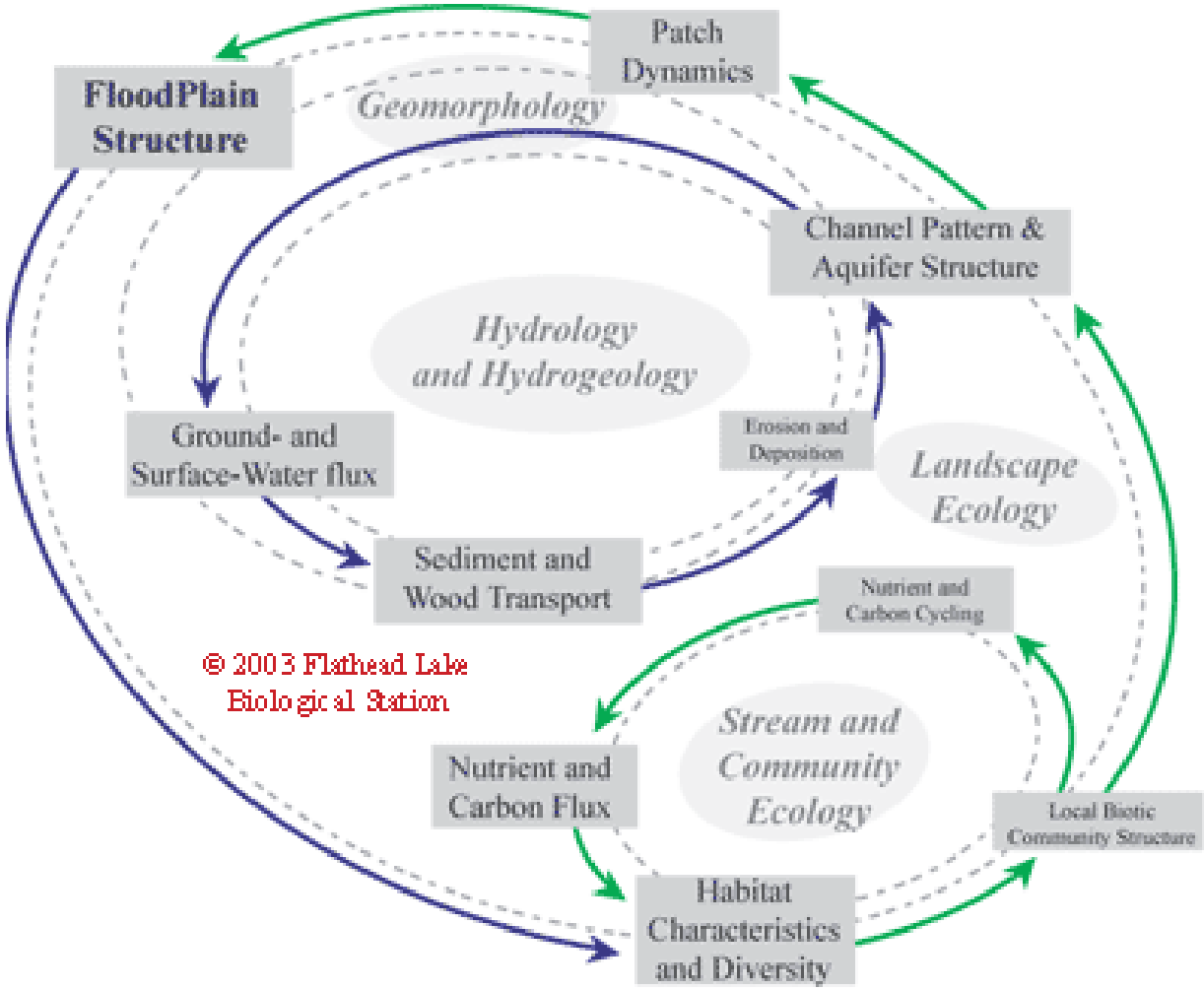
Level -1 ~ Controlling Processes

Level -2 ~ Noise

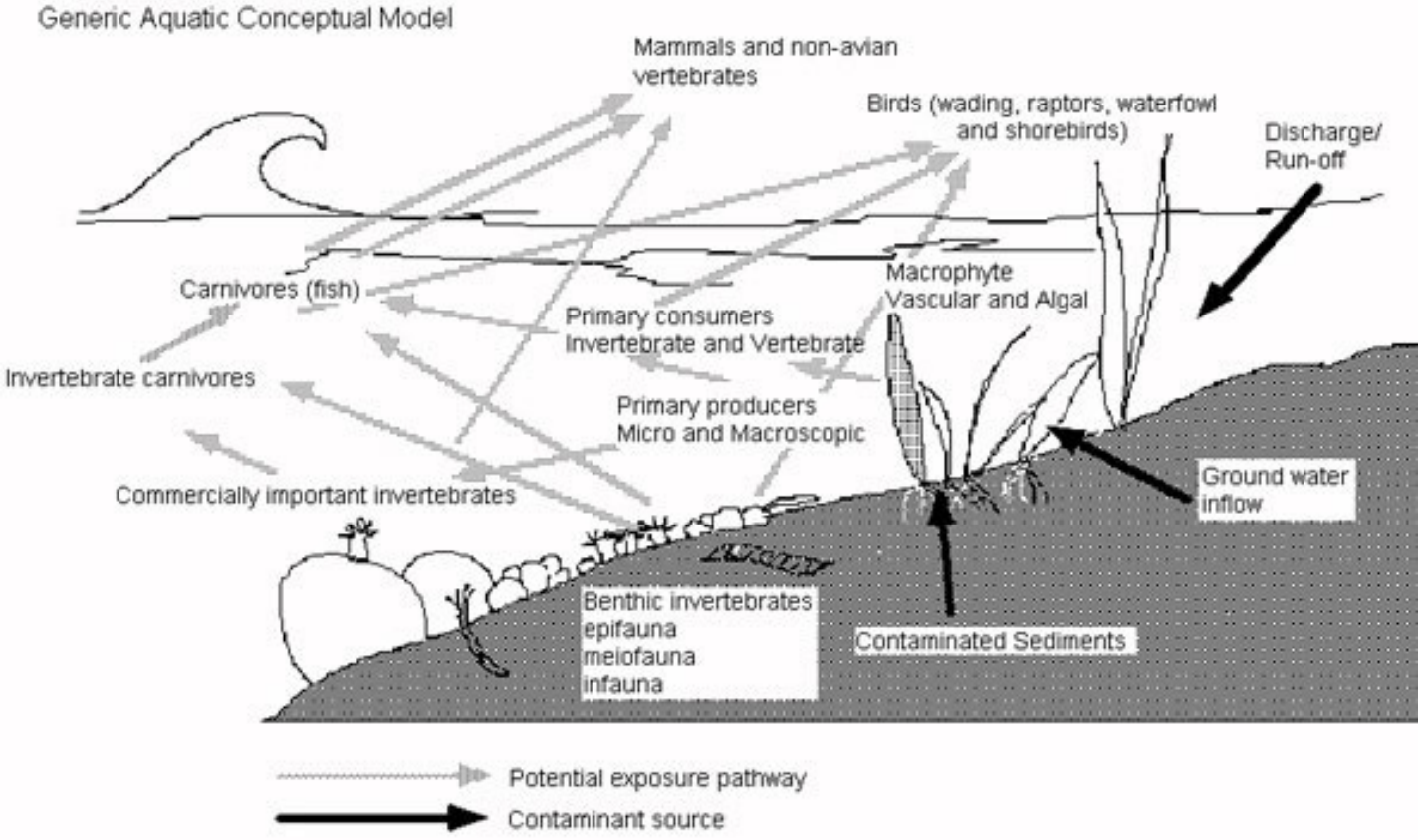
# Conceptual Models

- Henderson and O'Neil (2004)
- Six Step Approach
  - ID Model Objectives, Uses
  - T&S Scales or Model Boundaries
  - ID Structural Components
  - ID Sources of Change
  - Review the Model
  - Implement the Model

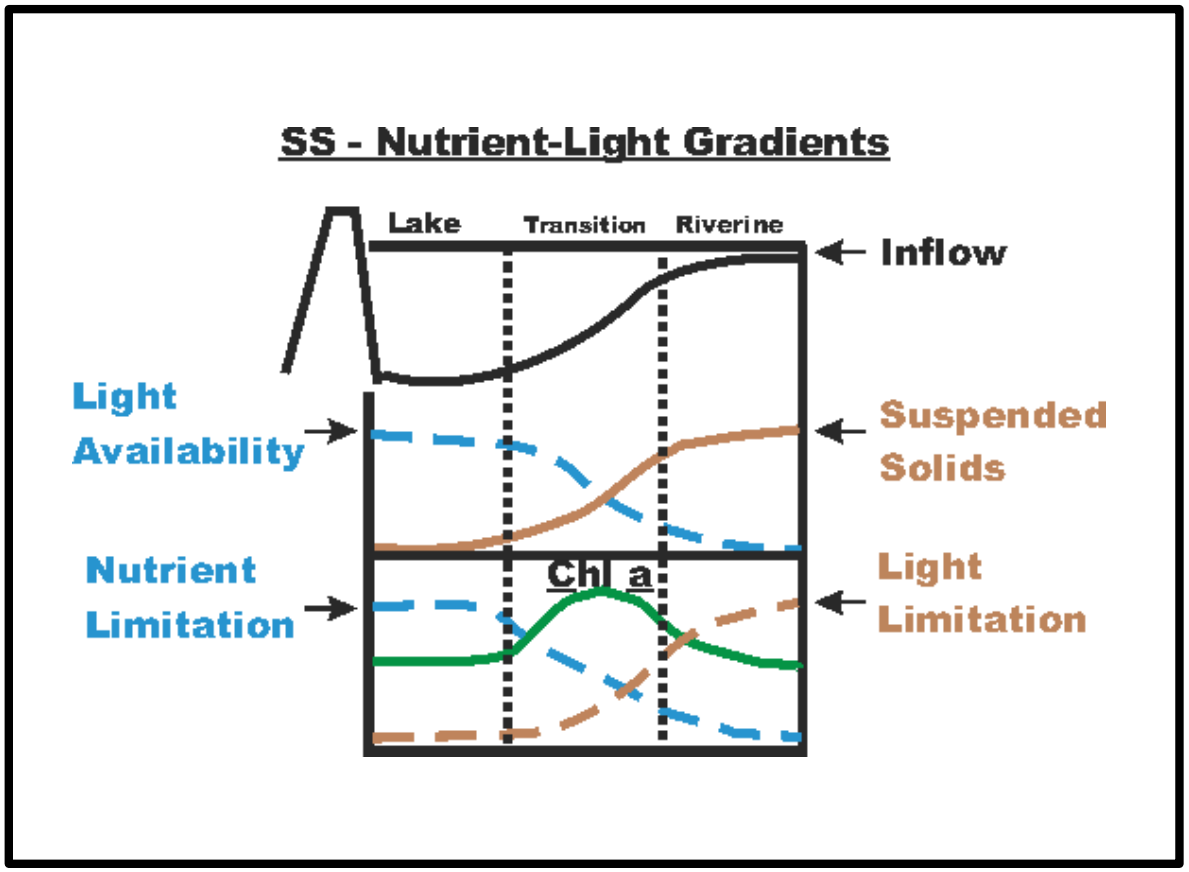
# Flood Plain Restoration

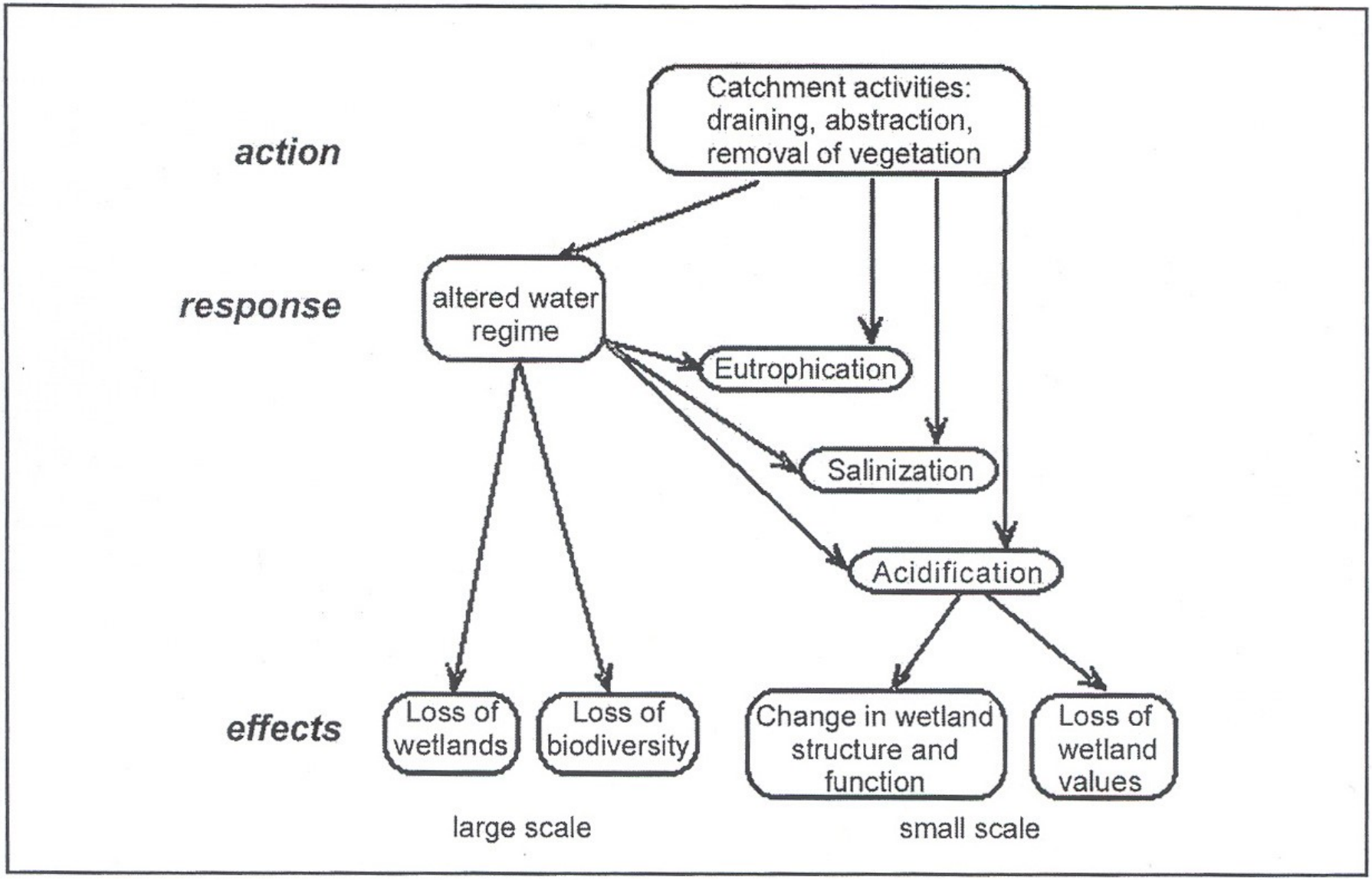


# Lake Restoration - Sediment

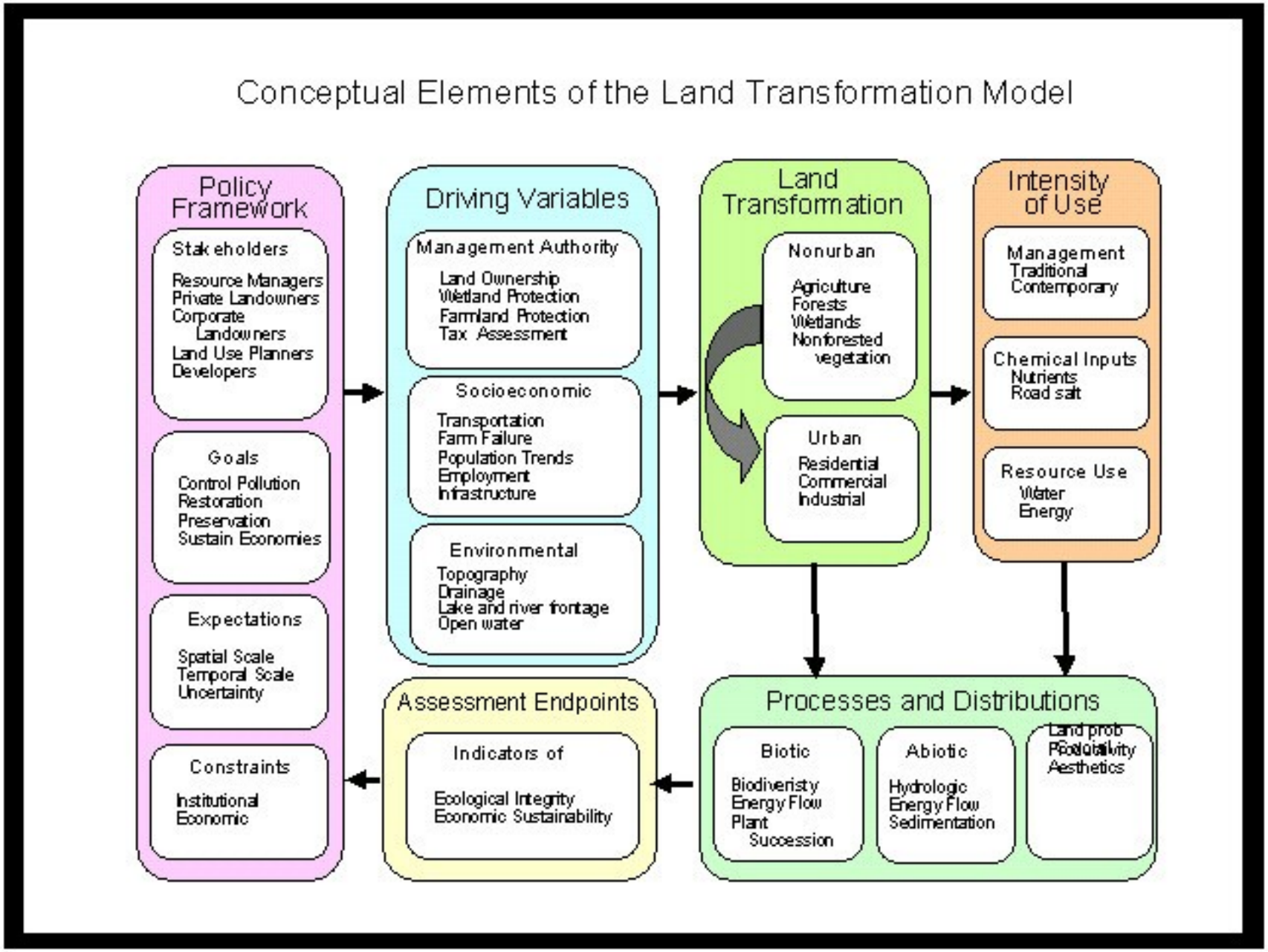


# Reservoir Gradients/Transition

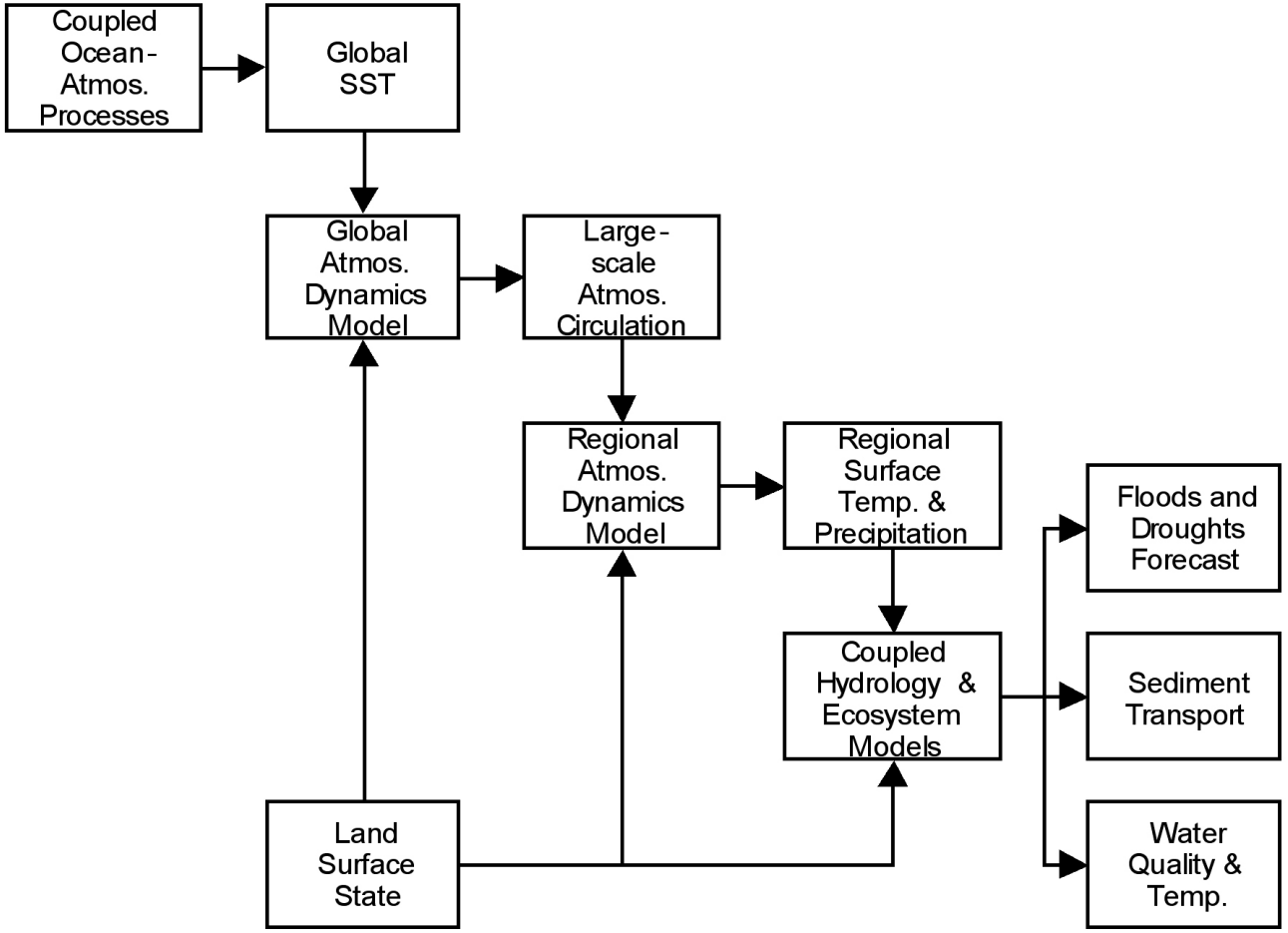



action
response
effects
Catchment activities: draining, abstraction, removal of vegetation
altered water regime
Eutrophication
Salinization
Acidification
Loss of wetlands
Loss of biodiversity
Change in wetland structure and function
Loss of wetland values
large scale
small scale

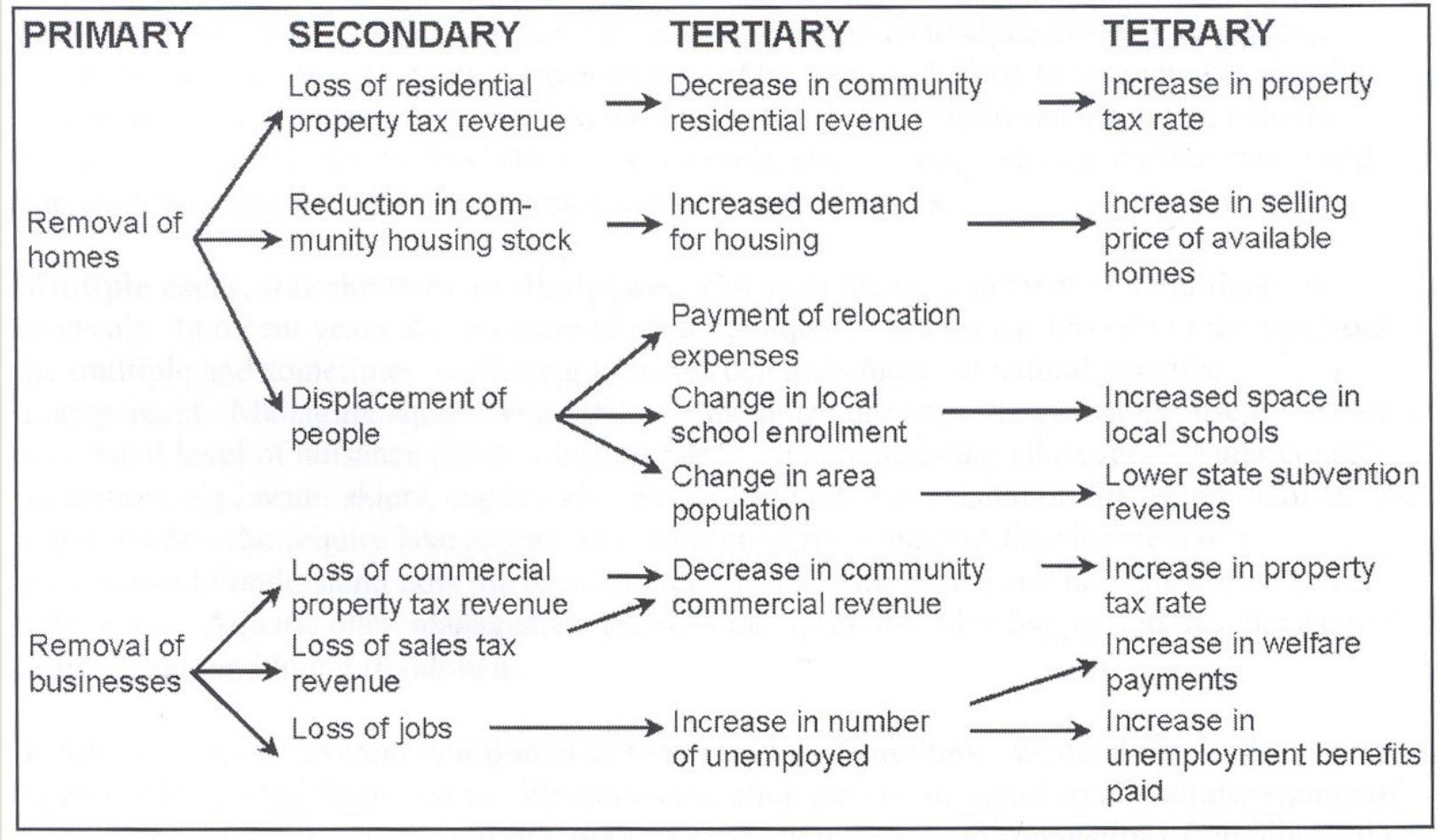
# Policy-Science Interactions



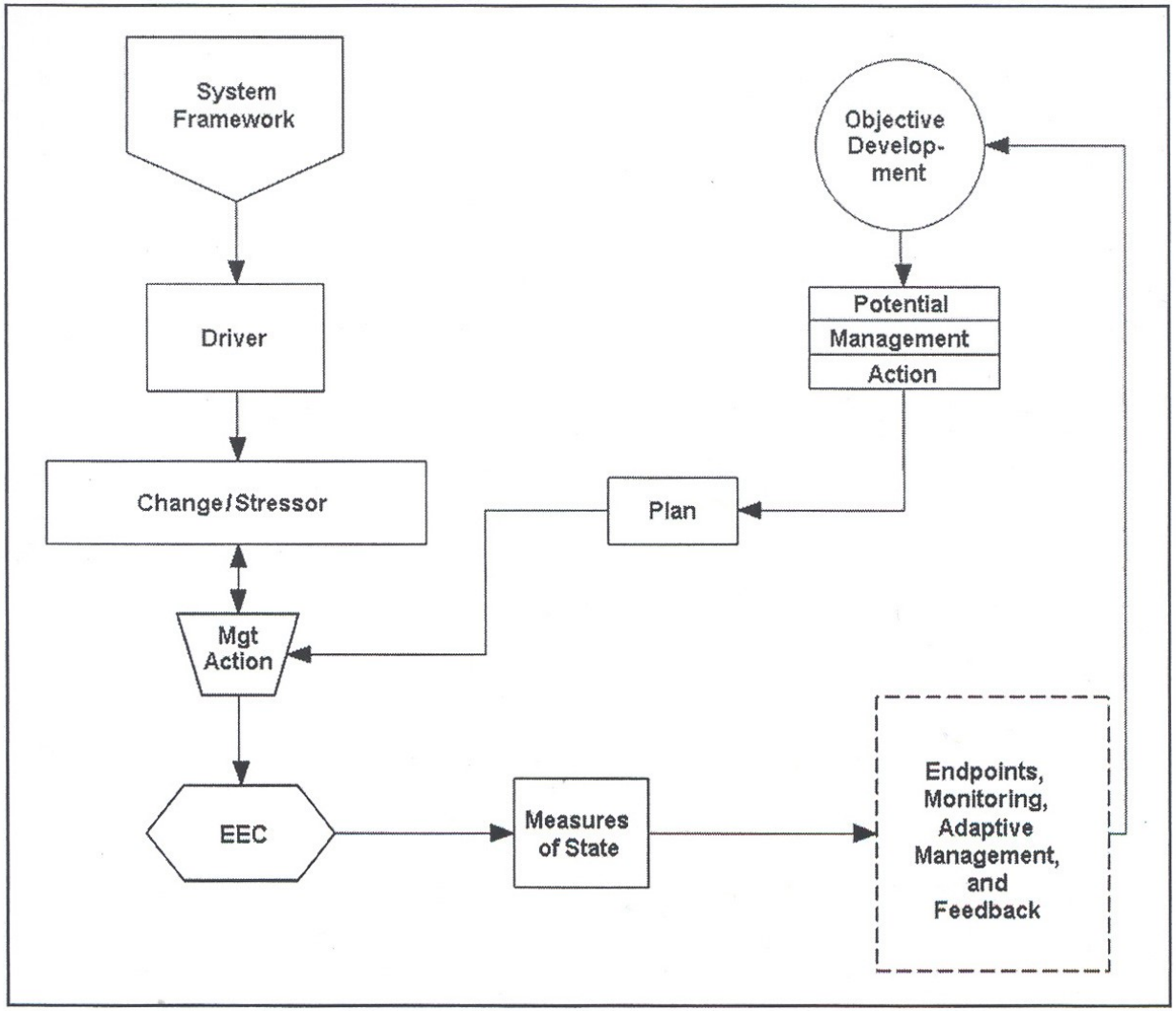
# Global Change and Ecohydrology



# Transportation Impact Model

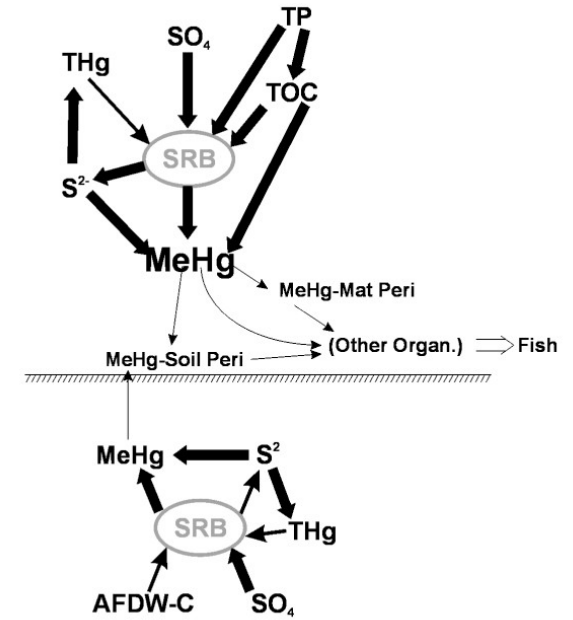

PRIMARY
SECONDARY
TERTIARY
TETRARY
Removal of homes
Loss of residential property tax revenue
Decrease in community residential revenue
Increase in property tax rate
Reduction in community housing stock
Increased demand for housing
Increase in selling price of available homes
Displacement of people
Payment of relocation expenses
Change in local school enrollment
Increased space in local schools
Change in area population
Lower state subvention revenues
Removal of businesses
Loss of commercial property tax revenue
Decrease in community commercial revenue
Increase in property tax rate
Loss of sales tax revenue
Increase in welfare payments
Loss of jobs
Increase in number of unemployed
Increase in unemployment benefits paid

# UMR Schematic Model

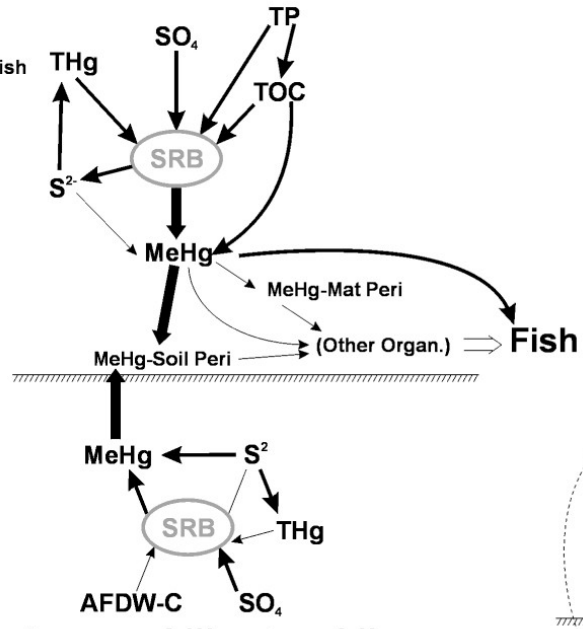


# So. FL Everglades Model

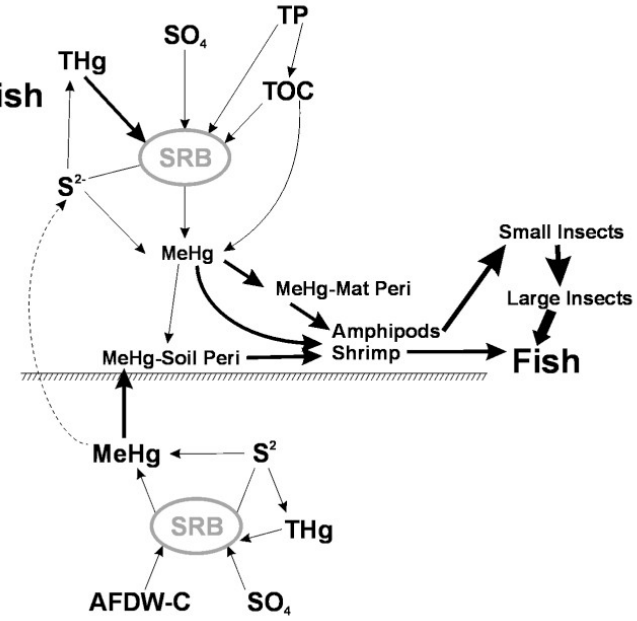
## Mercury Interactions: Conceptual Models




Above Alligator Alley




Between Alligator Alley and Tamiami Trail




Below Tamiami Trail

Note: Arrow size proportional to importance of interaction.

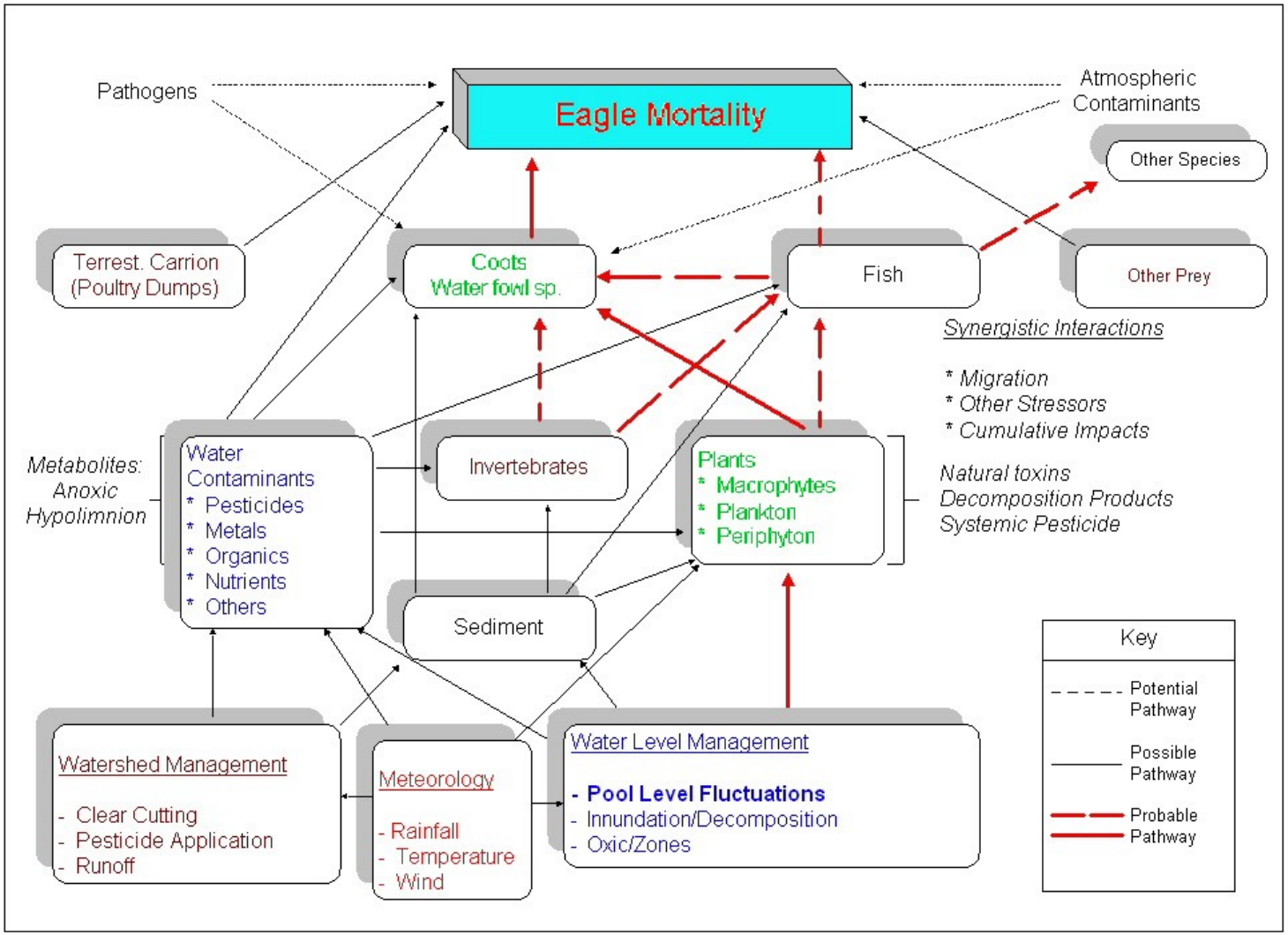



Figure 1. Conceptual Model of Eagle Mortality

# Order of Magnitude Estimates

- Rivers
  - Reynolds No. Re = □□L/□

    Re ~ 2000 > turbulent, < 2000 laminar flow
- Reservoirs
  - Froude No. Fr = $QL/V[(\square\square/\square)gz_m]^{1/2}$

    Fr ~ 1/□ << strongly stratified
- Estuaries
  - Richardson No. Ri = $(\square\square/\square)gQ/WU_t^{1/3}$
  - Well mixed 0.08 < Ri < 0.8 strongly stratified

# OME (Con't)

- Corps Reservoir Data Base
  - Drainage Area/Surface Area DA/SA
    - DA/SA < 10 – Shore/Near-shore Imp.
    - DA/SA > 50 – Far upstream unimp.
  - Aspect Ratio L/W
    - L/W < 4 – Both longitudinal & lateral imp.
    - L/W > 4 – Longitudinal dominate

# Empirical Relationships

- Rivers
  - DA and Q
    - $Q = 2x10^6 DA^{0.73}$ (Average Annual Q)
    - $Q_t = 0.73\ DA + 6.3$ ($R^2 = 0.6$) (Total Ann. Q)
  - Nutrients
    - $log chl = -1.92 + 1.96 logTP - 0.30(logTP)^2 + 0.12 logDA$ ($R^2 = 0.74$)

# Empirical Relationships (Con't)

- Reservoirs
  - Plunge Point
    - $hp = (1/F_d^2)^{1/3} (Q_i^2/W_c^2 g \Delta\rho/\rho)^{1/3}$
  - Nutrients
    - $[TP_x] = [Tp_i]\exp(-\lambda x)$ Plug flow Model
    - log chl a = -1.58 + 2.84 log TP - 0.67 (log TP)$^2$
  - Fish ($MEI = TDS/z_m$)
    - $log10H = 0.925 + 0.56 log10\ MEI - 0.15 log MEI^2$

      H = Reservoir Sport Fish Harvest, kg/ha

# Empirical Relationships (Con't)

- Estuaries
  - Resident Time
    - $FRT = (S_s-S_e/S_s)V/Q_f$
    - $PRT = (31 + 5.8 (10^8)/[86400(5.4 + 14.7 Q_f)]$
  - Nutrients
    - $Log_{10}chl = -3.7 +4.3log_{10}TN-0.9(log_{10}TN)^2$ $(R^2 = 0.84)$
    - $Log_{10}chl = 0.1 + 1.0log_{10}TP$ (N:P >20) $(R^2 = 0.74)$

# Time and Space Considerations

- Taxonomy of Indicators
- Time – Space Scales of Empirical Relationships
  - Average Seasonal Chlorophyll - Estuary
  - Fish Harvest ~ 5-10 years - Reservoir
  - Annual Discharge - Watershed

# Messages

- Begin With The End in Mind
- Make Sure You Know THE Questions
- Make It Relevant To Management

# Questions ?

# Discussion

# Integrated Process

## Selecting the Tools

# Messages

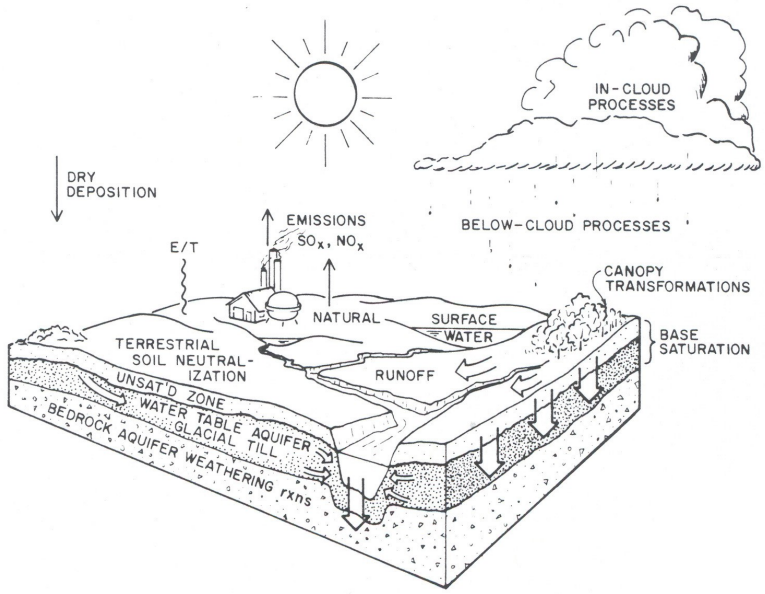
- Use a Suite of Tools
- Consider Time-Space Scales of Interest in Selecting Tools
- Keep It As Simple As Possible, But No Simpler

# An Acid Rain Story

- Story of Three Models
  - 100-200 Year Projections for Different Sulfate Emission Scenarios
  - Watershed – Lake – Stream Models
  - Three Different Philosophies
    - Research Tool (ILWAS)
    - Engineering Tool (MAGIC)
    - Steady-State => Dynamic Tool (ETD)

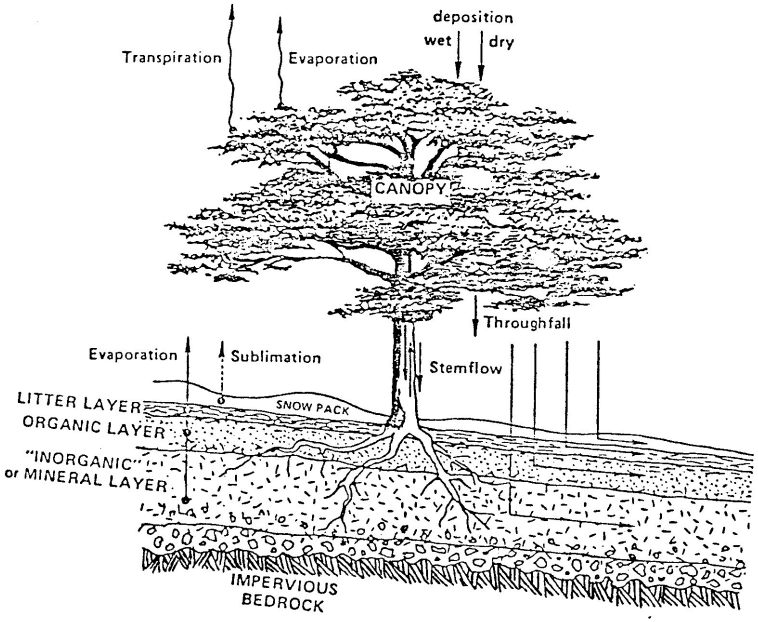
# Modeling Philosophies

- **ILWAS**
  - **Understand Acidification Processes**
- **MAGIC**
  - **Assess Long-Term Effects of Acidification**
- **ETD**
  - **Screen and Understand Lake Acidification**



# Modeling Philosophies (Con't)

- ILWAS
  - Daily Dynamics
- MAGIC
  - Annual Changes
- ETD
  - Steady-State and Dynamic Hydrology



# Major Processes

| Meteorological Data | MAGIC | ETD | ILWAS |
|---|---|---|---|
| Interval | Mo/Yr | Day | Day |
| Precip | m | mm | cm |
| Rel. Humid | – | % | % |
| Min/Max Air Temp | □C | | □C |
| Ave Air Temp | | □C | |
| Cloud Cover | – | Frac. | Frac. |
| Wind | | km/d | m/s |

# Major Processes (cont.)

| Atmospheric Process | MAGIC | ETD | ILWAS |
|---|---|---|---|
| Wet Deposition | X | X | X |
| Dry Deposition | X | X | X |
| Hydrologic Processes | | | |
| Snow Sublimation | - | X | X |
| ET | X | X | X |
| Interception | - | - | X |
| Snowmelt | X | X | X |

# Major Processes (cont.)

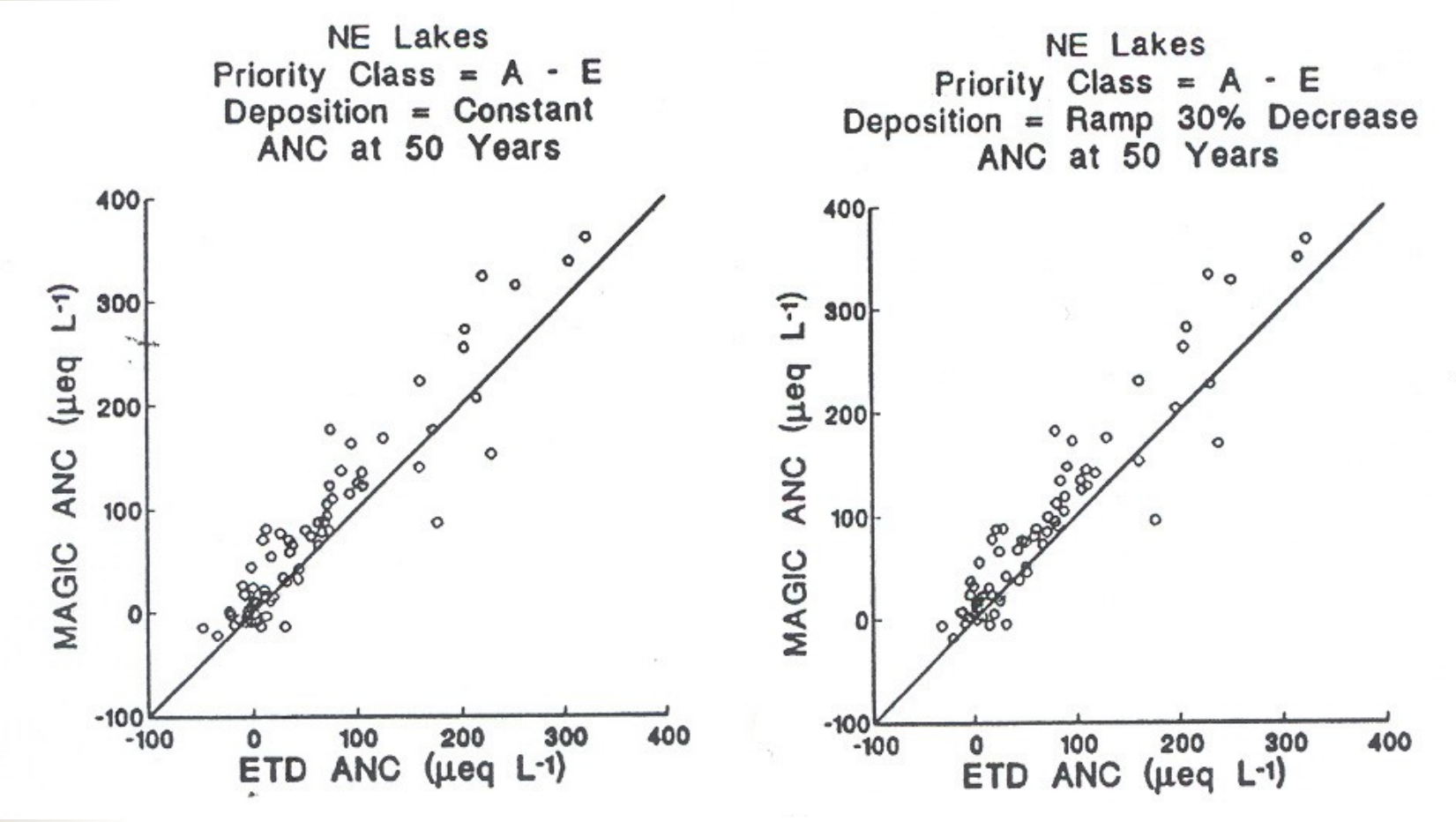
| Hydrologic Process. (Con't) | MAGIC | ETD | ILWAS |
|---|---|---|---|
| Overland Flow | X | X | X |
| Soil Freezing. | – | X | X |
| Macropore Flow | X | – | – |
| Unsaturated Subsurface Q | X | X | X |
| Saturated Subsurface Q | X | X | X |
| Stream Flow | X | – | X |
| Lake Stratification | – | – | X |
| Lake Ice Formation | – | – | X |

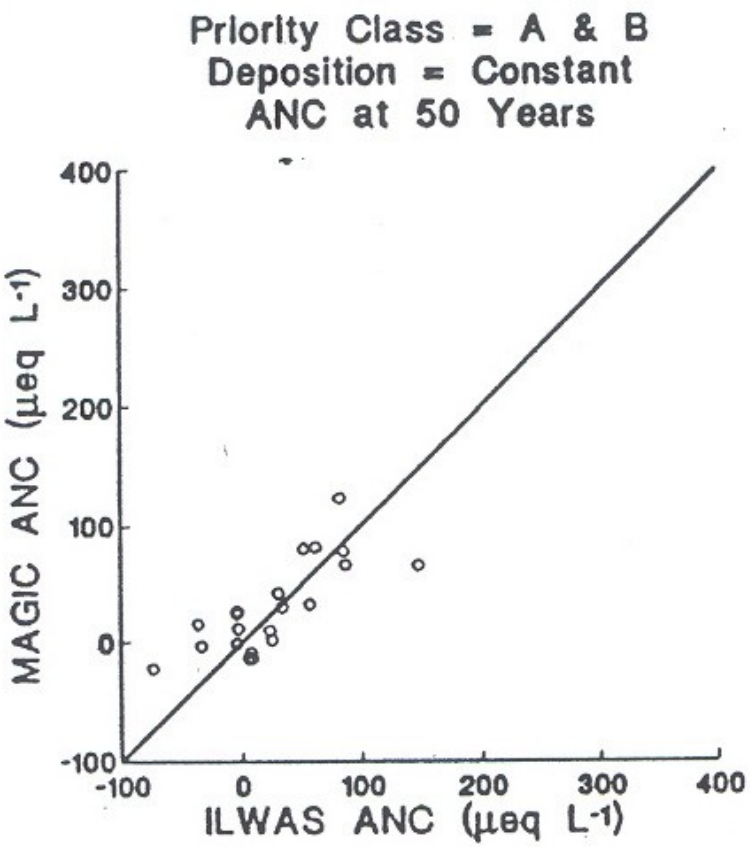
# Major Processes (cont.)

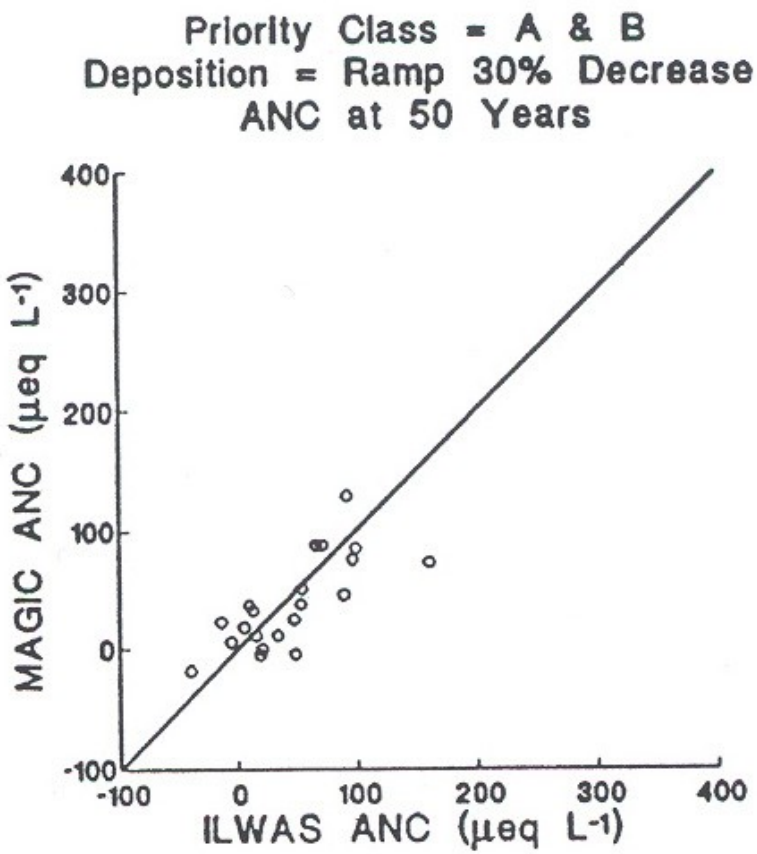
| Geochem. Processes | MAGIC | ETD | ILWAS |
|---|---|---|---|
| $H_2CO_3$ Chemistry | X | X | X |
| Al Chemistry | X | – | X |
| Org. Acid Chemistry | X | – | X |
| Weathering | X | X | X |
| Anion Retention | X | X | X |
| Cation Exchange | X | X | X |

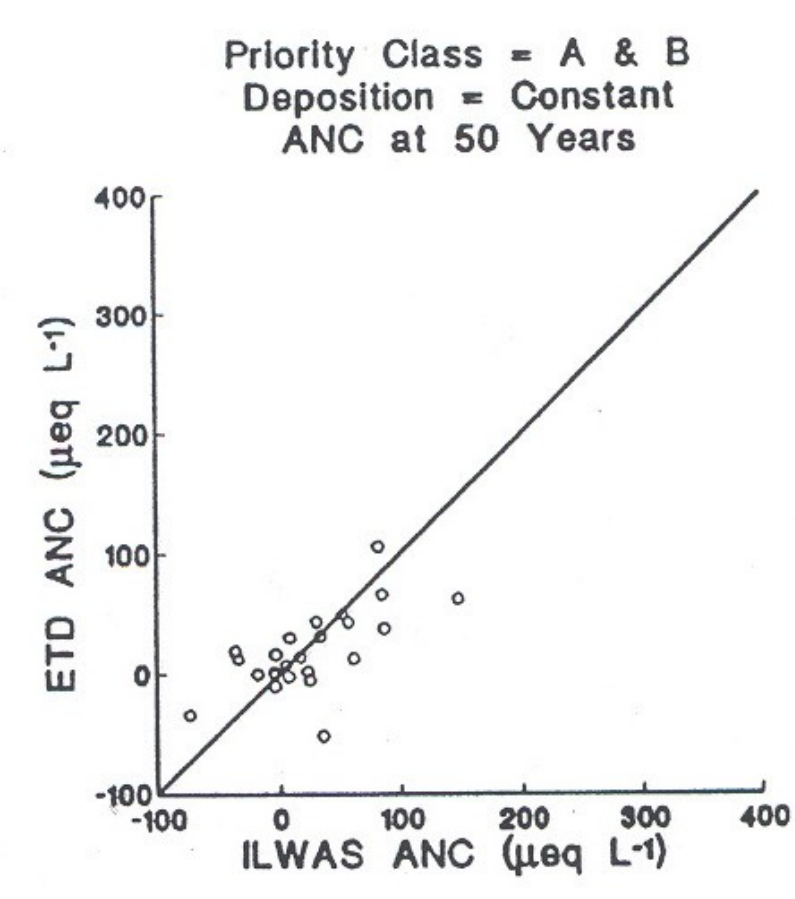
# Major Processes (cont.)

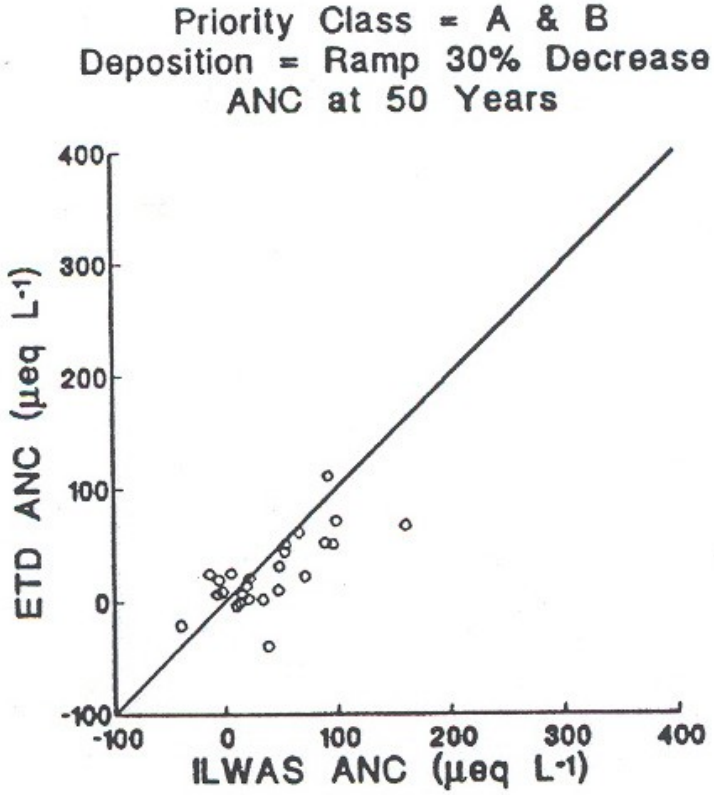
| Biogeochem. Processes | MAGIC | ETD | ILWAS |
|---|---|---|---|
| Lake $SO_4$ Reduction | ~ | S | S |
| Soil Nitrification | ~ | – | X |
| Nutrient Uptake | ~ | – | X |
| Canopy Interception | – | – | X |
| Litter Decay | – | – | X |
| Root Respiration | – | – | X |

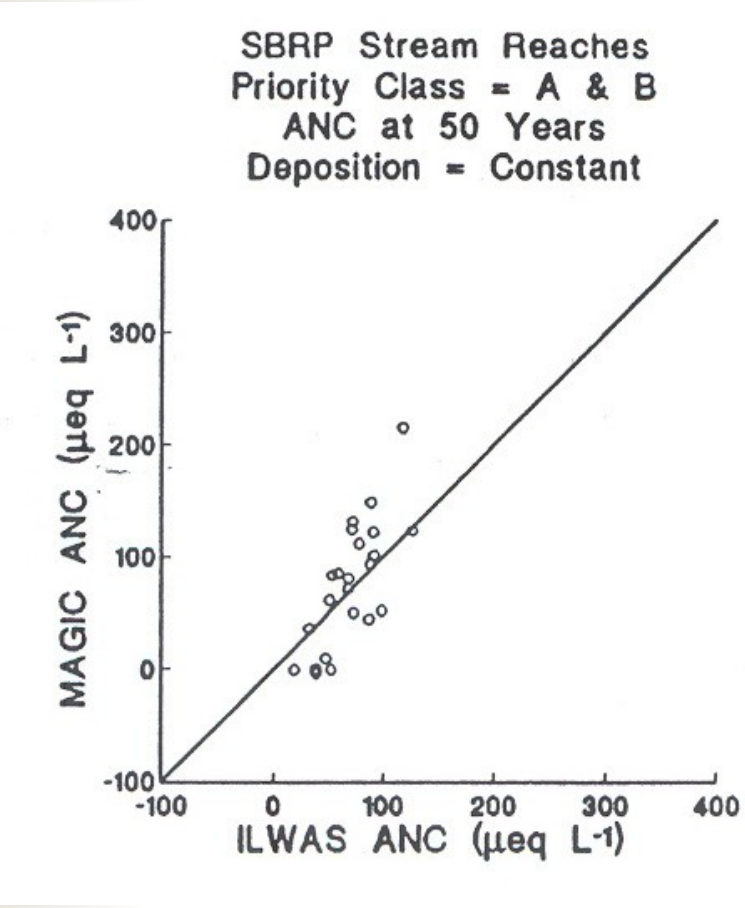

NE Lakes
Priority Class = A - E
Deposition = Constant
ANC at 50 Years
MAGIC ANC (µeq L-1)
ETD ANC (µeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400
NE Lakes
Priority Class = A - E
Deposition = Ramp 30% Decrease
ANC at 50 Years
MAGIC ANC (µeq L-1)
ETD ANC (µeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400

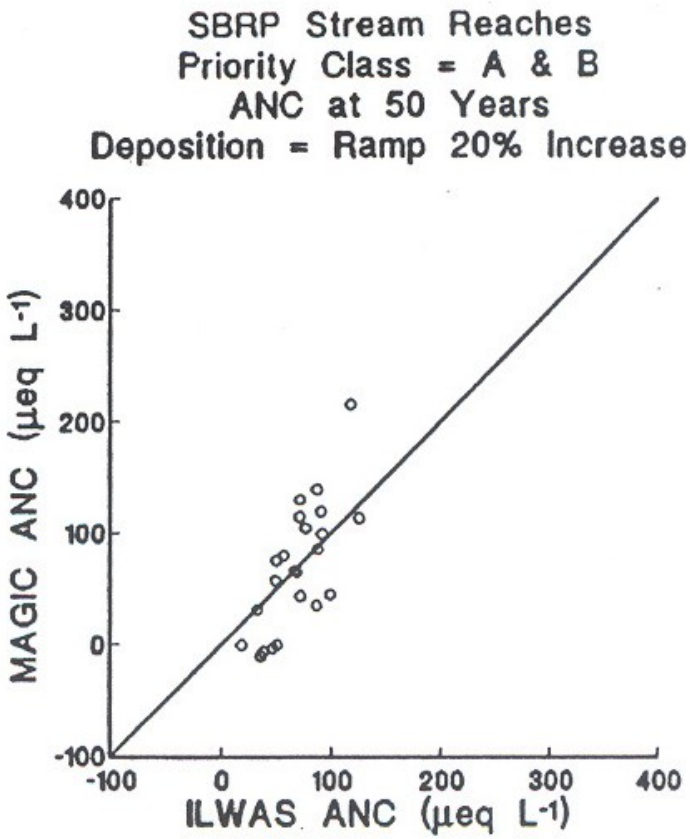

Priority Class = A & B
Deposition = Constant
ANC at 50 Years
MAGIC ANC (μeq L-1)
ILWAS ANC (μeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400

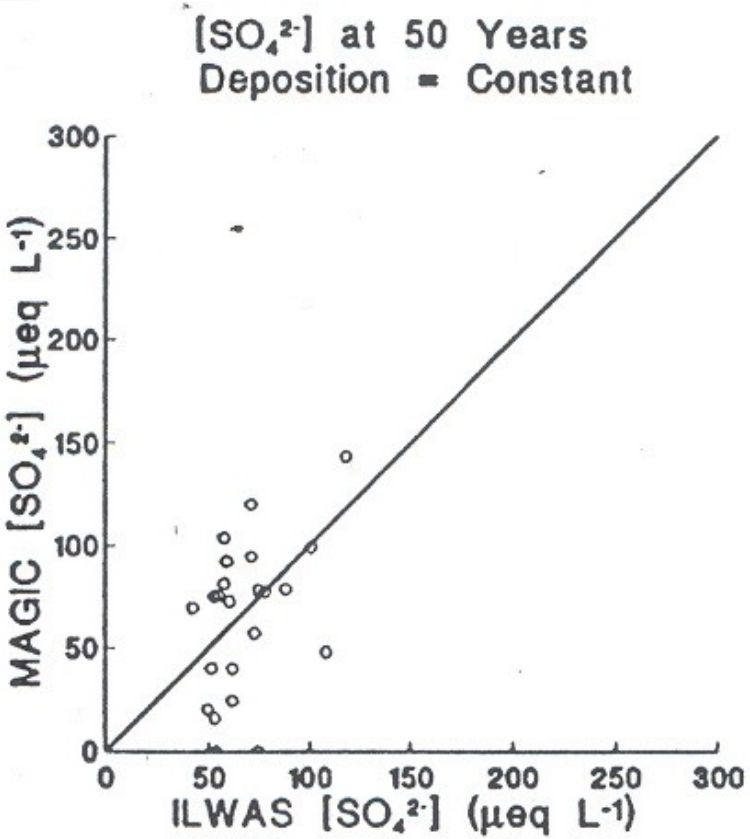

Priority Class = A & B
Deposition = Ramp 30% Decrease
ANC at 50 Years
MAGIC ANC (μeq L-1)
ILWAS ANC (μeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400

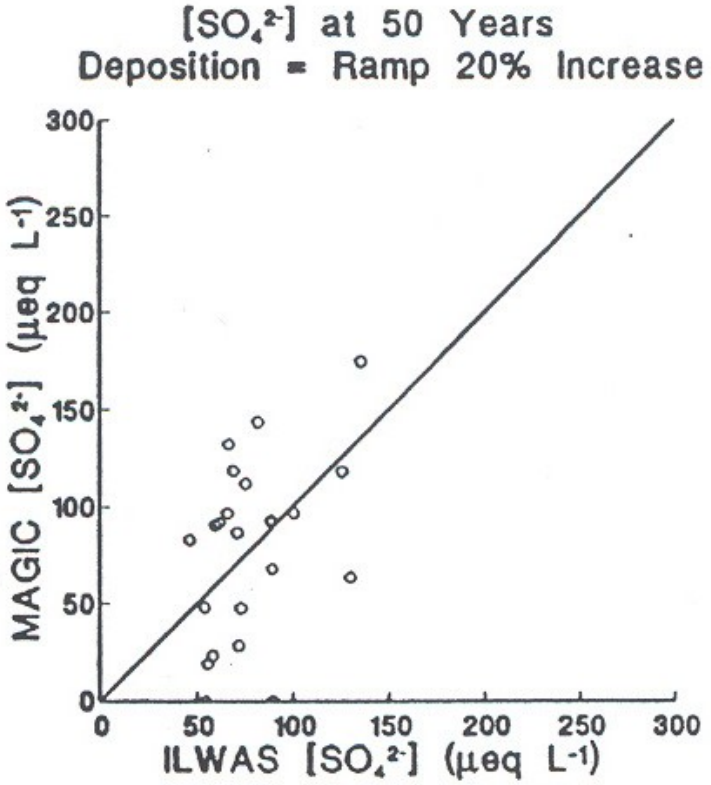

Priority Class = A & B
Deposition = Constant
ANC at 50 Years
ETD ANC (µeq L-1)
ILWAS ANC (µeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400

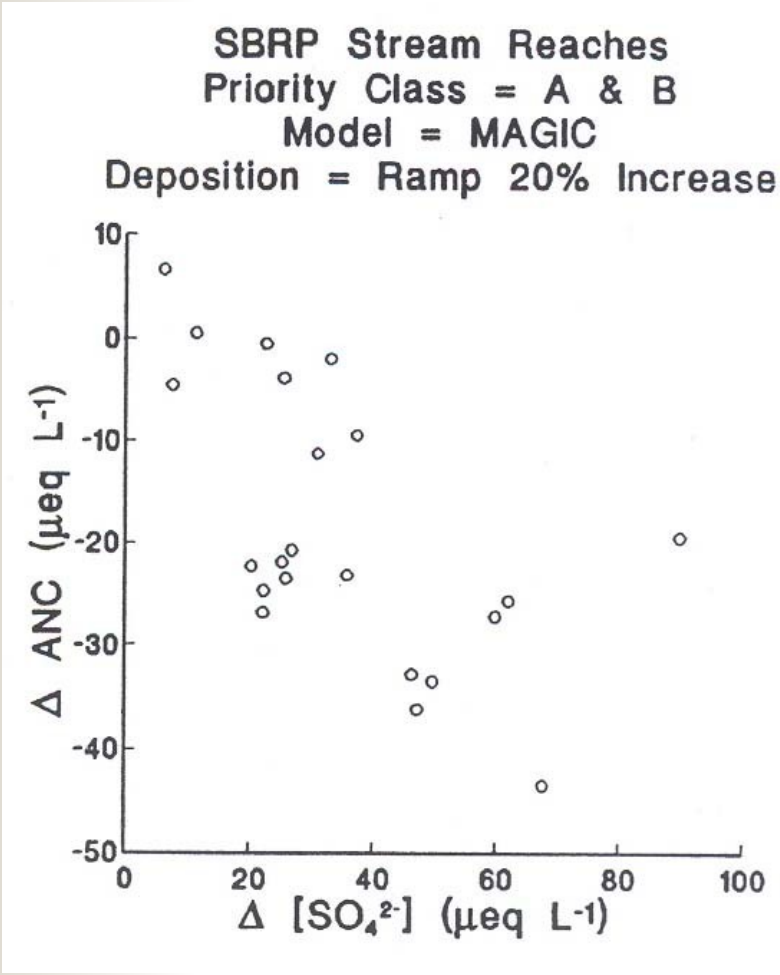

Priority Class = A & B
Deposition = Ramp 30% Decrease
ANC at 50 Years
ETD ANC (µeq L-1)
ILWAS ANC (µeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400

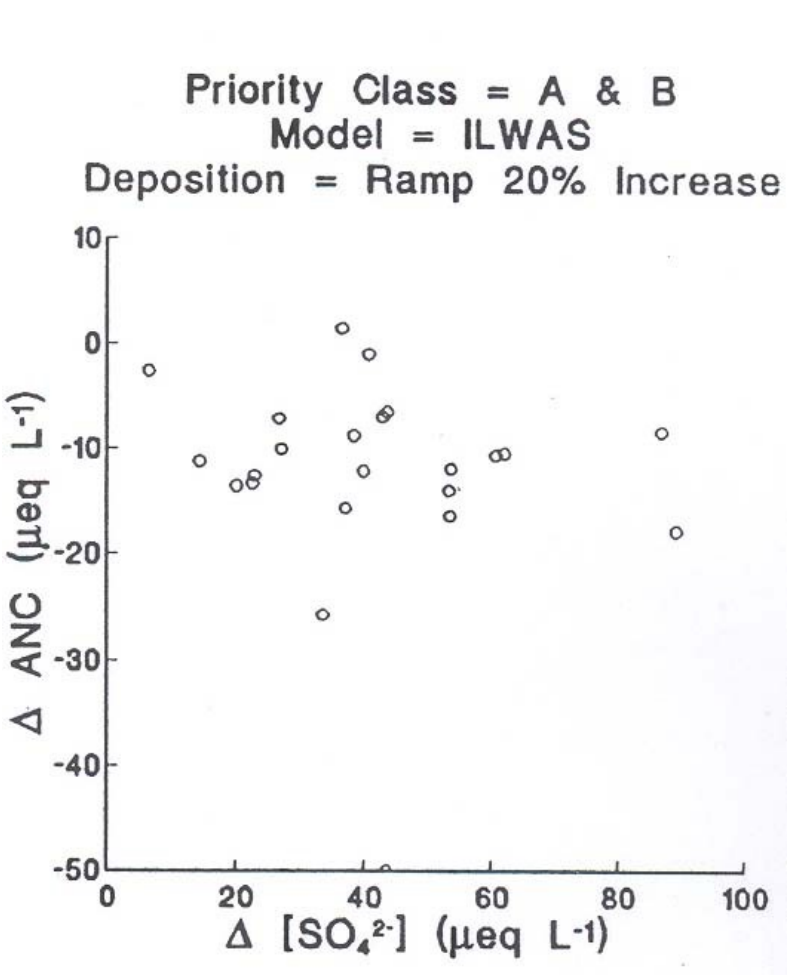

SBRP Stream Reaches
Priority Class = A & B
ANC at 50 Years
Deposition = Constant
MAGIC ANC (µeq L-1)
ILWAS ANC (µeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400


SBRP Stream Reaches
Priority Class = A & B
ANC at 50 Years
Deposition = Ramp 20% Increase
MAGIC ANC (µeq L-1)
ILWAS ANC (µeq L-1)
400
300
200
100
0
-100
-100
0
100
200
300
400


[SO4 2-] at 50 Years
Deposition = Constant
MAGIC [SO4 2-] (µeq L-1)
ILWAS [SO4 2-] (µeq L-1)
0
50
100
150
200
250
300


[SO4 2-] at 50 Years
Deposition = Ramp 20% Increase
MAGIC [SO4 2-] (µeq L-1)
ILWAS [SO4 2-] (µeq L-1)
0
50
100
150
200
250
300


SBRP Stream Reaches
Priority Class = A & B
Model = MAGIC
Deposition = Ramp 20% Increase
Δ ANC (μeq L-1)
Δ [SO4 2-] (μeq L-1)
10
0
-10
-20
-30
-40
-50
0
20
40
60
80
100


Priority Class = A & B
Model = ILWAS
Deposition = Ramp 20% Increase
Δ ANC (μeq L-1)
Δ [SO4 2-] (μeq L-1)
10
0
-10
-20
-30
-40
-50
0
20
40
60
80
100

# Holling's 3 Rules of Thumb

- Need Three Qualitatively Different Speeds of Processes
- 3 to 5 Sets of Variables Adequately Describe System Dynamics
- Have Non-linear Causation and Multistable Behavior

# Hierarchy Theory

Level +2 ~ Constant

Level +1 ~ Slowly Varying

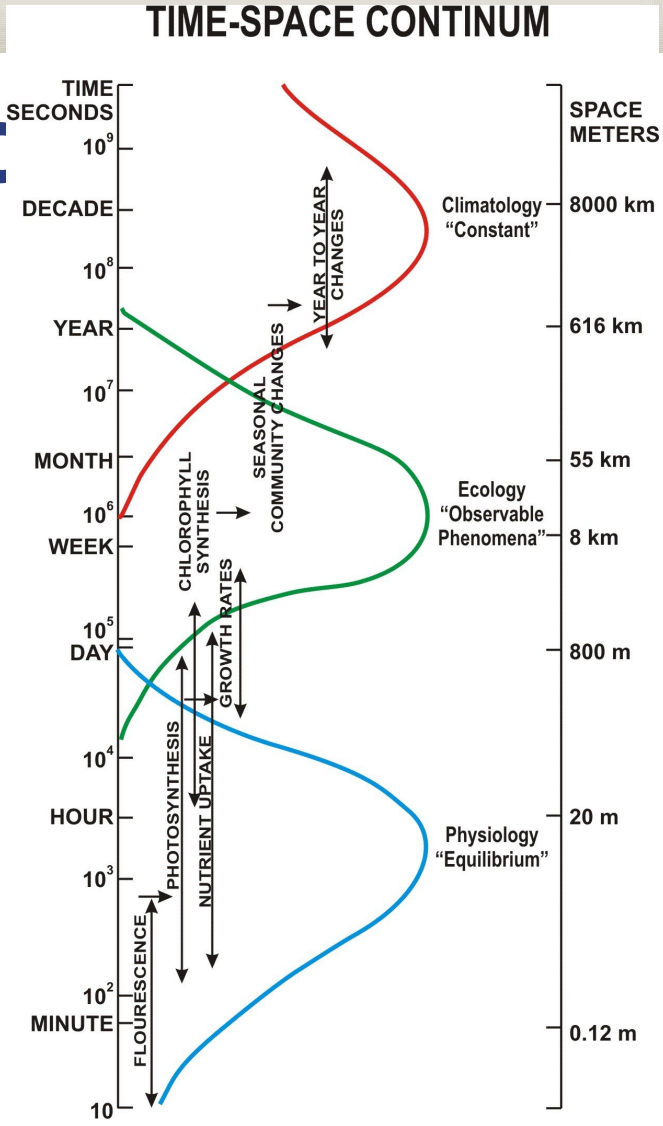
Level +0 ~ Management Endpoint

Level -1 ~ Controlling Processes

Level -2 ~ Noise

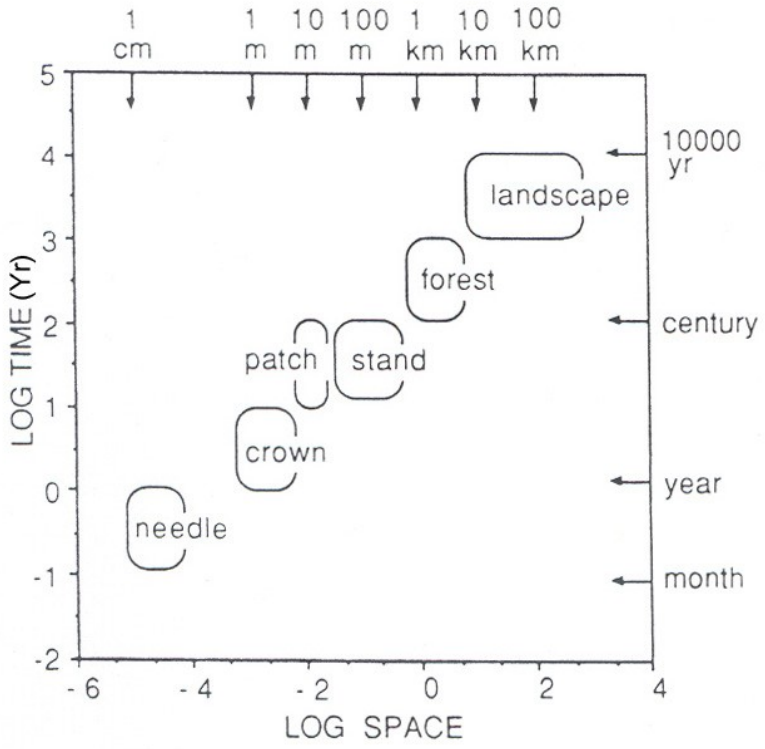
# Plankton Hierarc

- Levels +1, 0, -1 in Green Curve
- Level –2 as Center of Mass in Blue Curve
- Level +2 As Center of Mass in Red Curve

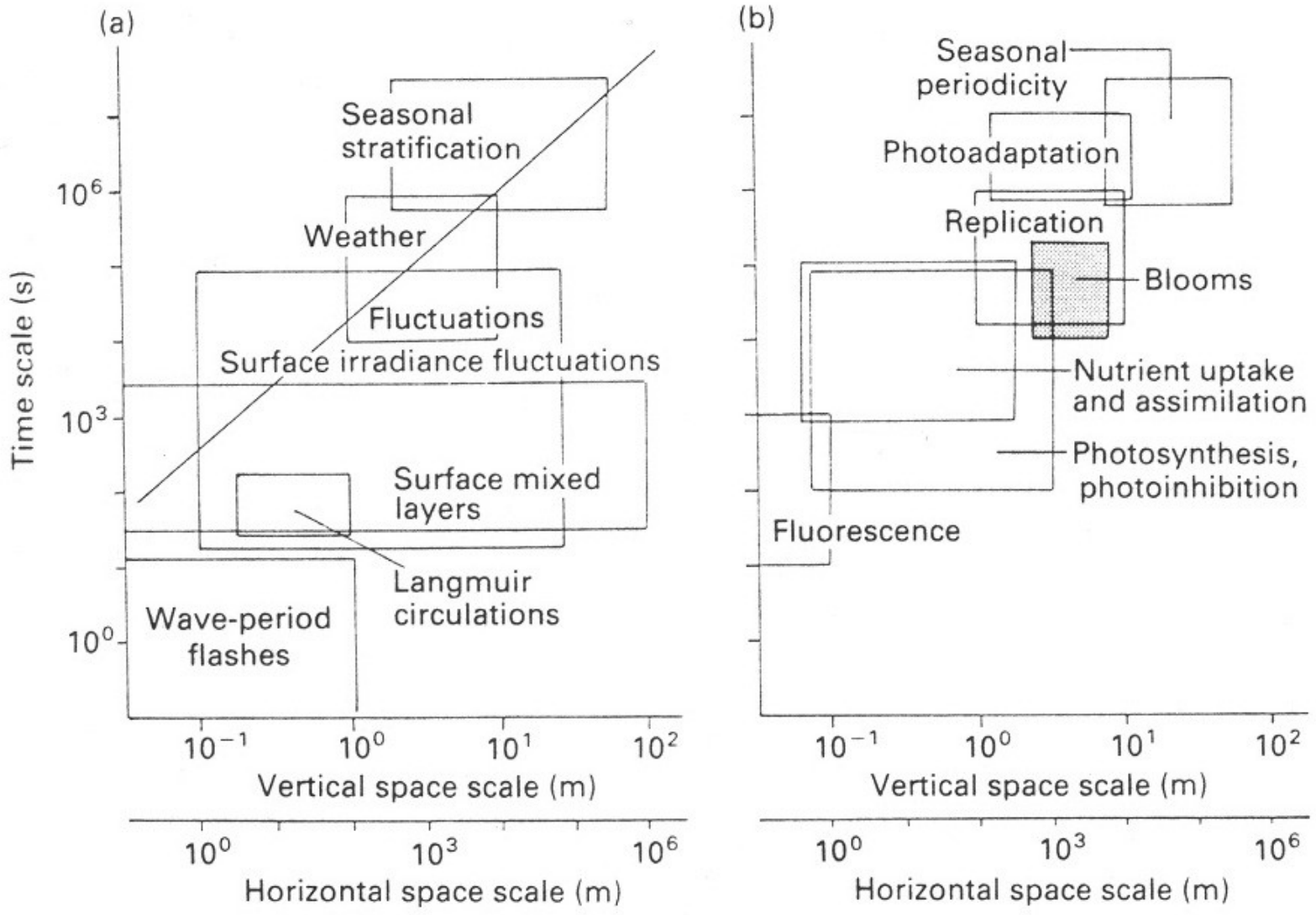


# Time – Space Inter-Relationships

- Rule of 10's
- 3 Qualitatively Different Speeds (T-S Scales)
- System Independent
  - Aquatic Systems
  - Terrestrial Systems
  - Atmospheric Systems
  - (Social and Economic Systems)



# 3-D Scales


(a)
Seasonal stratification
Weather
Fluctuations
Surface irradiance fluctuations
Surface mixed layers
Langmuir circulations
Wave-period flashes
Time scale (s)
$10^6$
$10^3$
$10^0$
$10^{-1}$ $10^0$ $10^1$ $10^2$
Vertical space scale (m)
$10^0$ $10^3$ $10^6$
Horizontal space scale (m)
(b)
Seasonal periodicity
Photoadaptation
Replication
Blooms
Nutrient uptake and assimilation
Photosynthesis, photoinhibition
Fluorescence
$10^{-1}$ $10^0$ $10^1$ $10^2$
Vertical space scale (m)
$10^0$ $10^3$ $10^6$
Horizontal space scale (m)

# Basin Variables & Time (NRC 2000)

| Variable | > 1000 yr | Decade to Century | Year to Decade |
|---|---|---|---|
| Geology | Constant | Constant | Constant |
| Climate | Constant (GCC) | Constant (GCC) | Constant |
| Vegetation | Variable | Slowly Varying | Constant |

# Basin Variables & Time (NRC 2000)

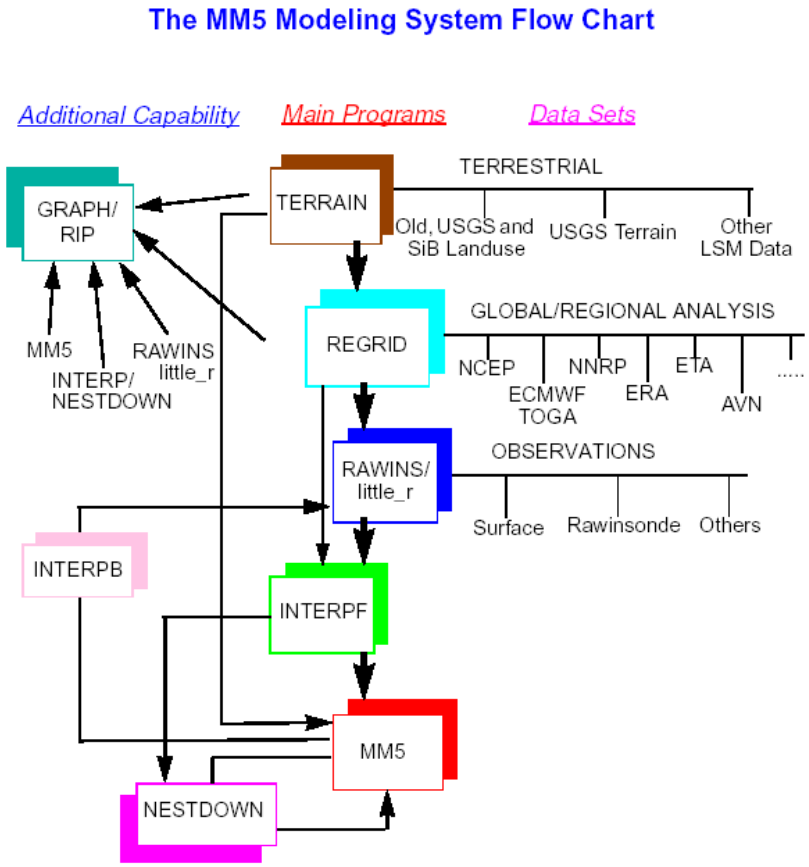
| Variable | > 1000 yr | Decade to Century | Year to Decade |
|---|---|---|---|
| Hydrology (Q, Sed/DA) | Variable | Constant | Constant |
| DA Network Morphology | Variable | Variable | Constant |
| Hillslope | Variable | Variable | Constan |

# Commonalities

- Acidification; Hg Contamination; Global Change; UMR Restoration; Other Large Scale Issues
  - Long Time Scales – Large Space Scales
  - Alternative Tools – Alternative Approaches
  - Not Either – Or; Both – And

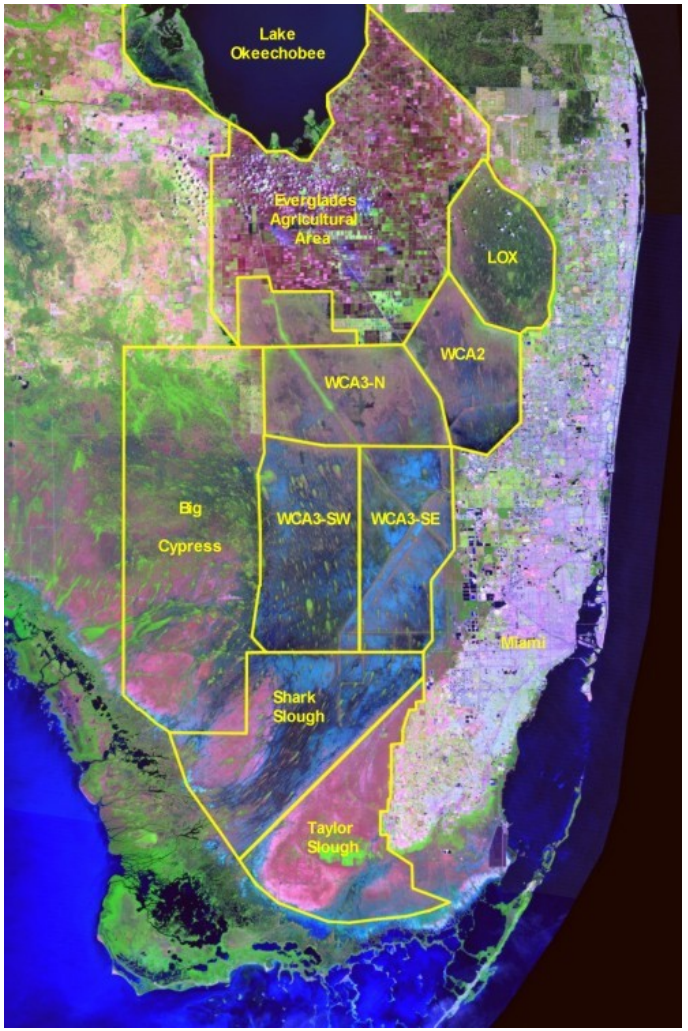
# Other Tools

- Downscaling – Upscaling GCM => Regional Modeling
- Reduced Form Equations
  - TAF
  - Reduced Form Equations



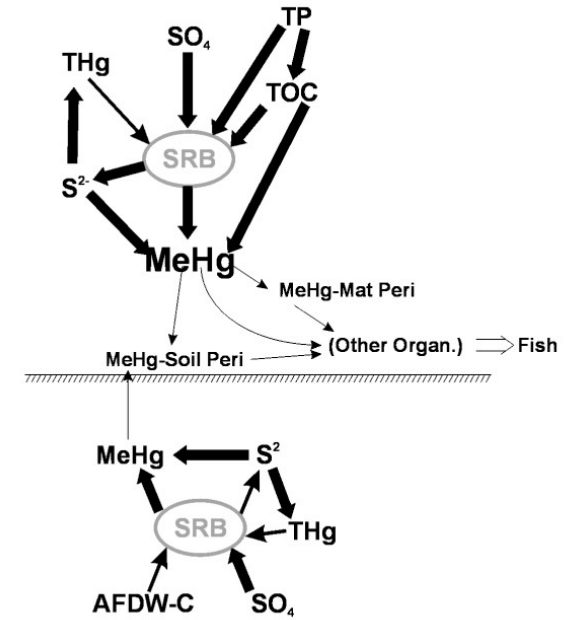
# Other Tools

- South Florida Everglades Ecosystem
  - SEM or Path Analysis
  - Mercury Cycling Model
  - Different T-S Scales

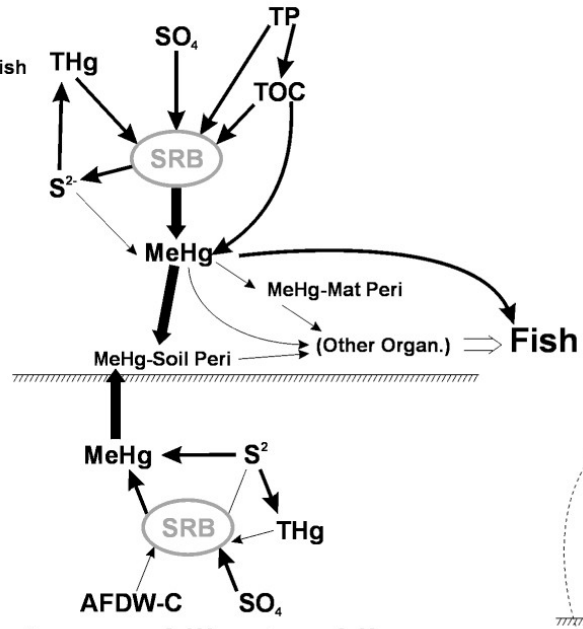


# So. FL Everglades Model

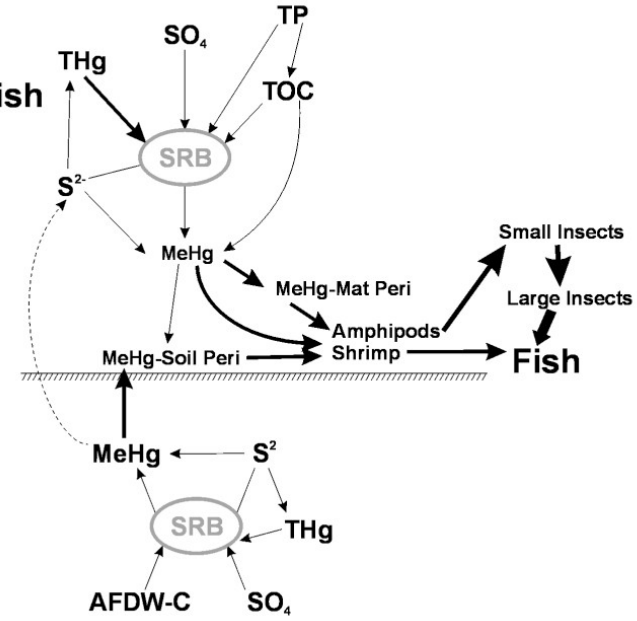
## Mercury Interactions: Conceptual Models




Above Alligator Alley




Between Alligator Alley and Tamiami Trail

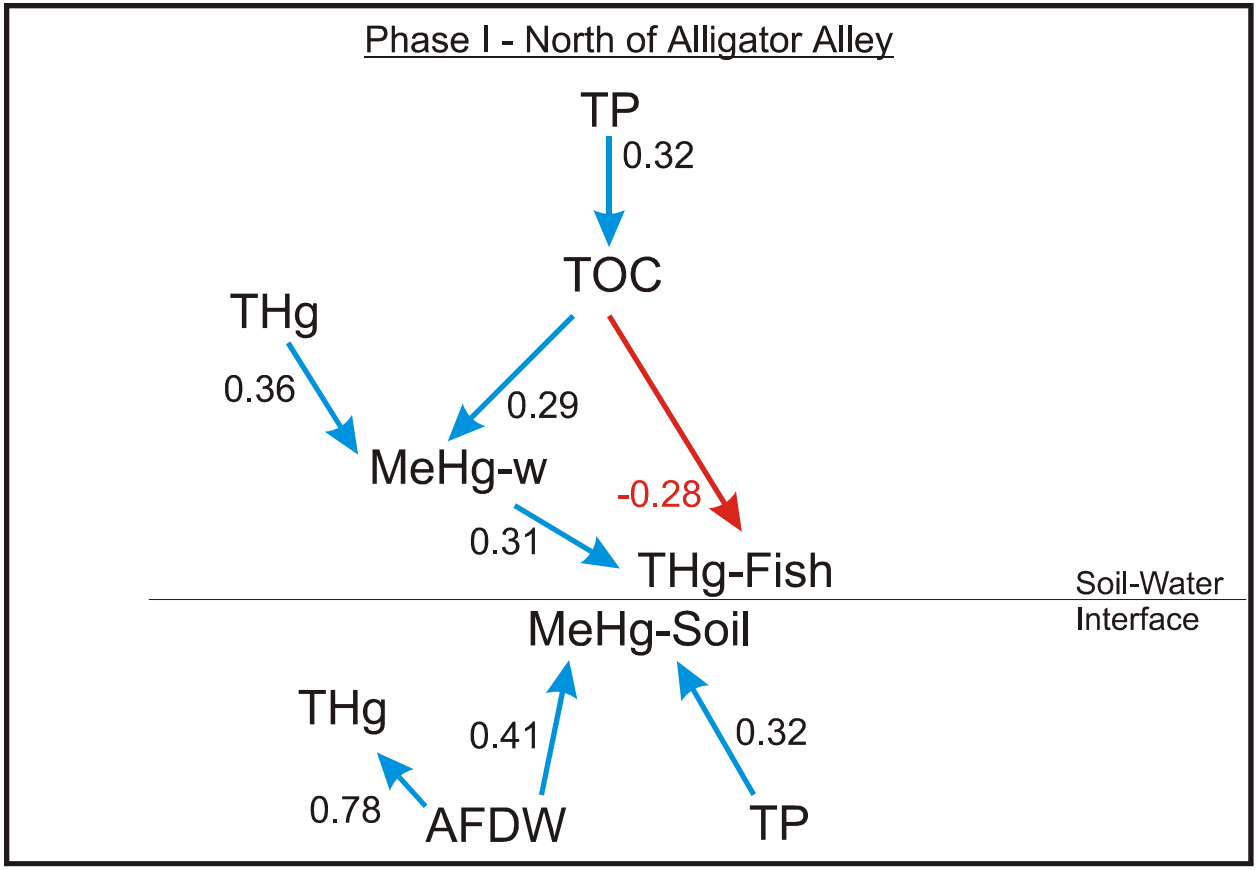



Below Tamiami Trail

Note: Arrow size proportional to importance of interaction.

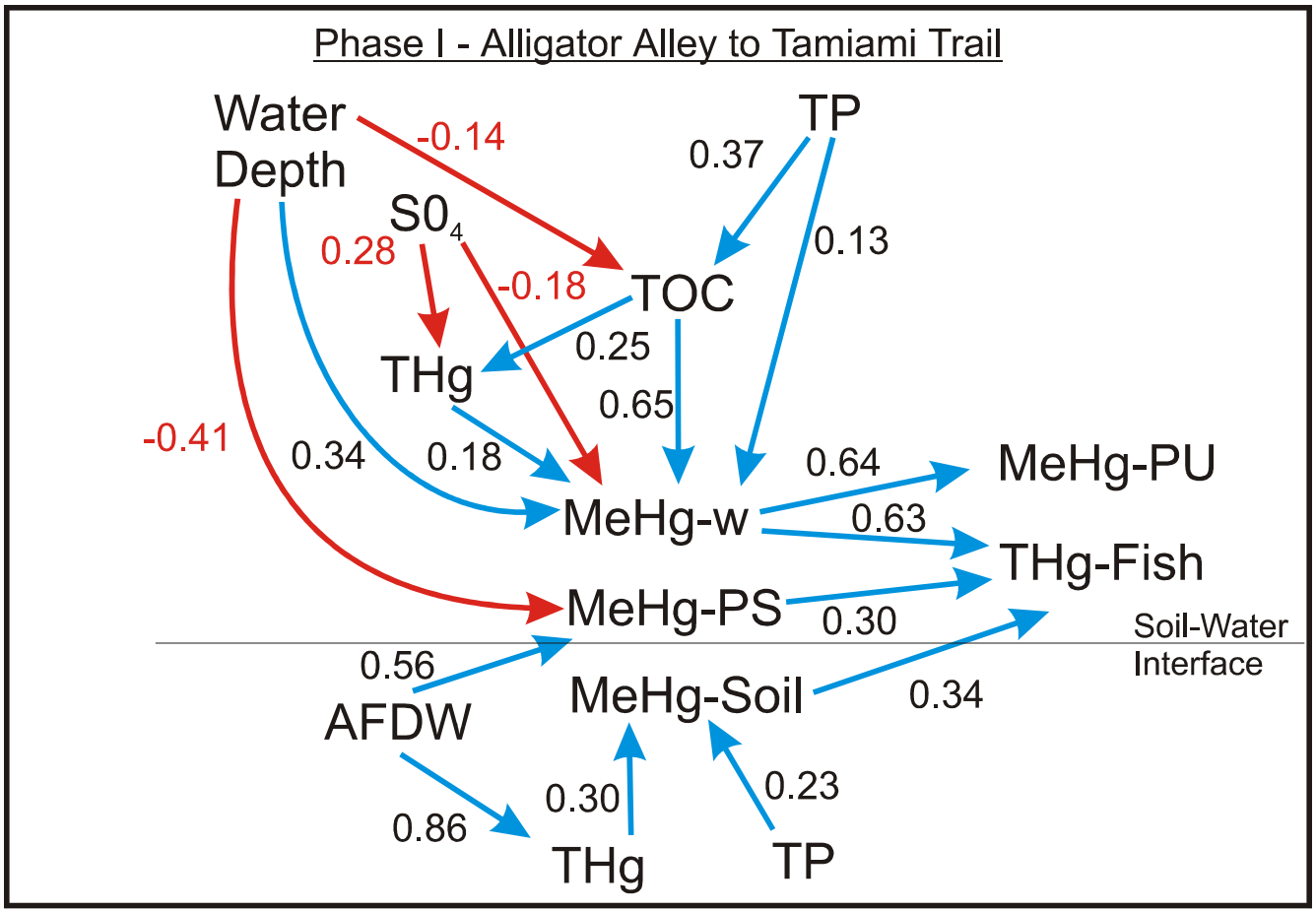
# North of Alligator Alley - Phase I

## High Concentrations



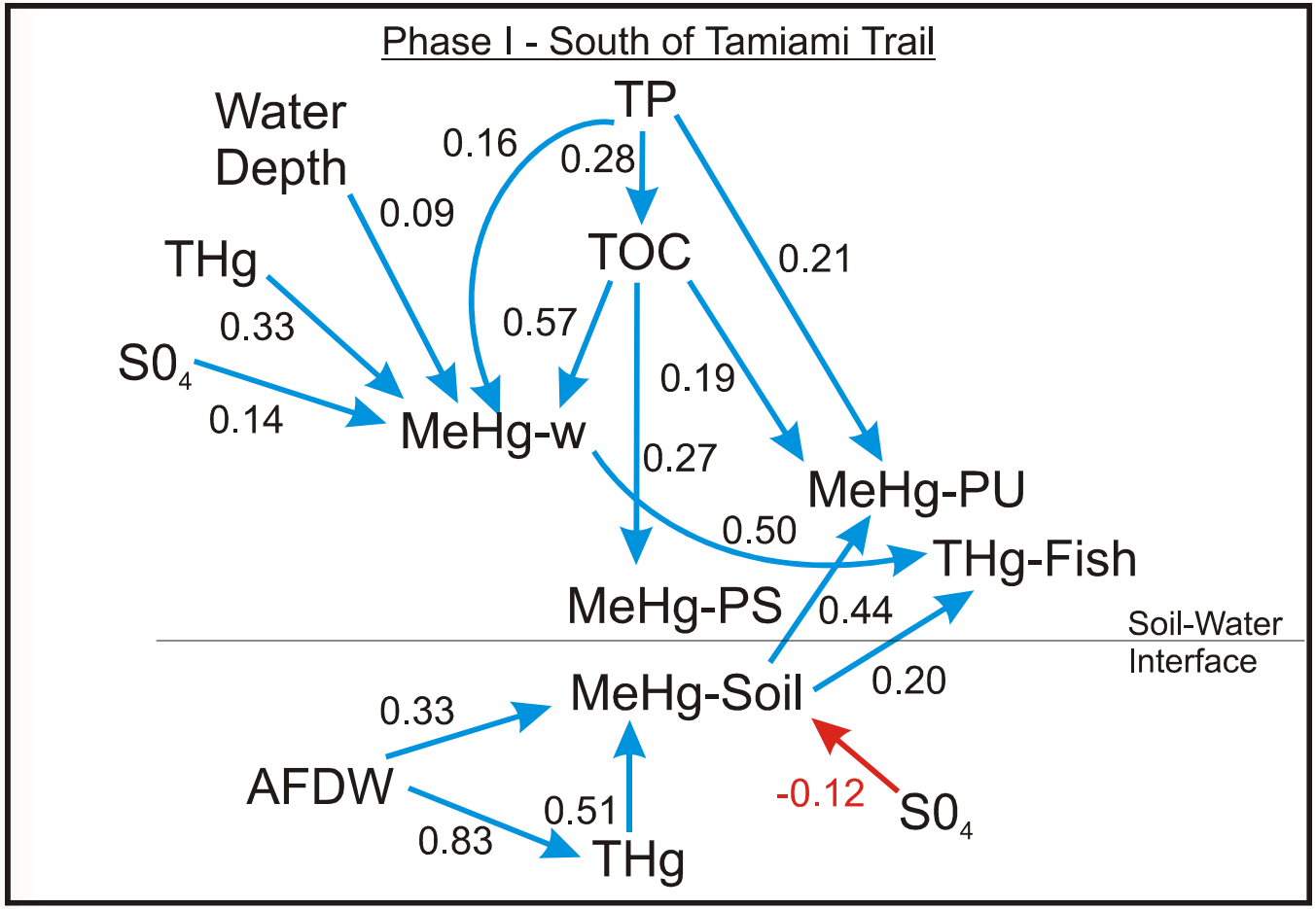
# Alligator Alley - Tamiami Trail

## Dynamic Area - Phase I



# South of Tamiami Trail - Phase I

## Low Concentrations



# Reduced Equations

- **WCA3-SE THg - Fish**
  - **log(THg-F) = 4.67-1.81 log(TOC) +0.47 log(MeHg)+0.43 log(MeHg-PU)**

    **$R^2$ = 0.64, n=28**
- **WCA3-SW THg-Fish**
  - **log(THg-F) = -0.52 log(S) + 0.33 log(MeHg)**

    **$R^2$ = 0.62, n = 22**

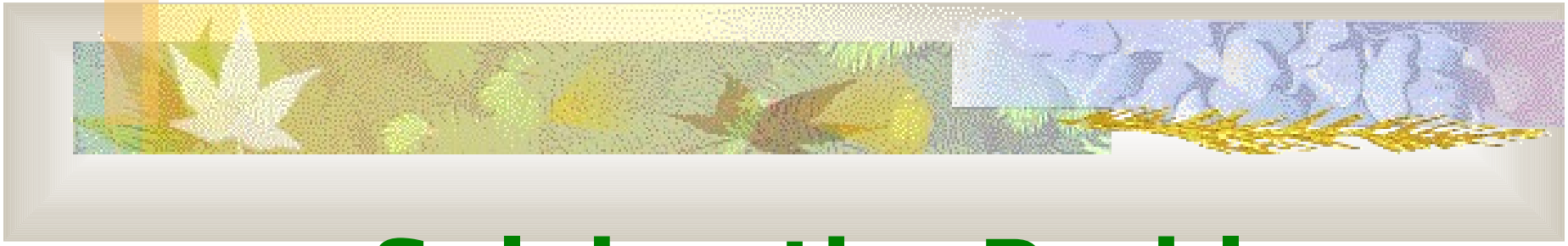
# Messages

- Use a Suite of Tools
- Consider Time-Space Scales of Interest in Selecting Tools
- Keep It As Simple As Possible, But No Simpler

# Questions ?

# Discussion

# Integrated Process



## Solving the Problem

# Messages

- Use Weight of Evidence Approaches
- Provide Risk or Uncertainty (Certainty) Estimates
- Tailor the Message to the Audience

# Weight of Evidence

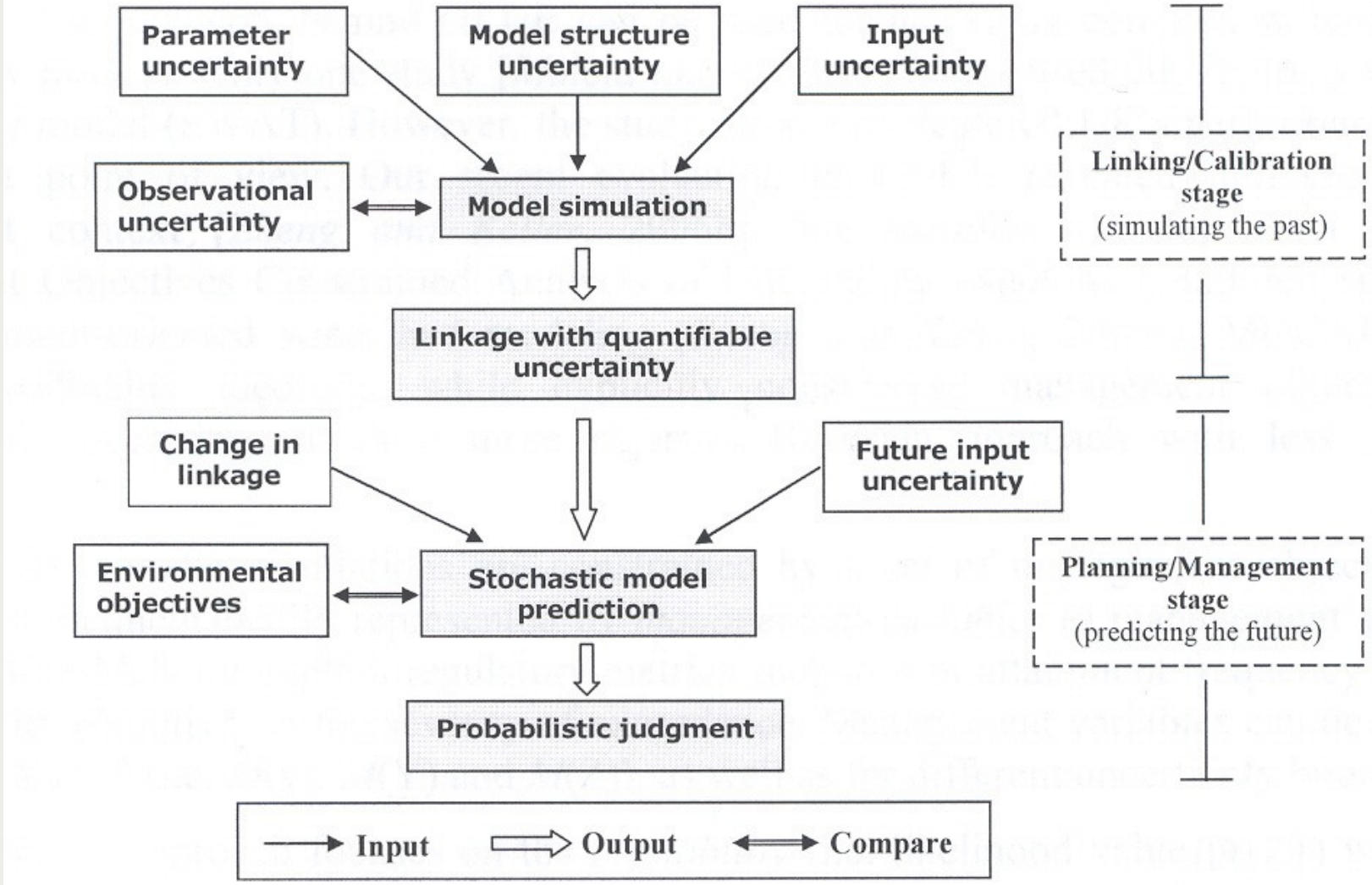
- Coupled Models  Integrated Models
  - Disparate Time – Space
  - Interface & Boundary Conditions
- Weight of Evidence
  - Multiple Results From Multiple Tools
  - Convergence or Divergence of Results
  - Formal Approaches Needed

# Weight of Evidence

- Need Better Weight of Evidence Approaches
  - Relative Risk Models
  - Normalization/Scaling Approaches
  - Intuitive Perspective
  - Expert Elicitation

# Certainty of Results

- **Uncertainty Typology (Krupnick et al. 2006)**
  - **Aleatory (randomness, chance)**
    - **Stocasticity**
  - **Epistemic (knowledge)**
    - **Input uncertainty**
    - **Parameter uncertainty**
    - **Structural uncertainty**
    - **Transboundary uncertainty**


Parameter uncertainty
Model structure uncertainty
Input uncertainty
Observational uncertainty
Model simulation
Linkage with quantifiable uncertainty
Change in linkage
Future input uncertainty
Environmental objectives
Stochastic model prediction
Probabilistic judgment
Linking/Calibration stage
(simulating the past)
Planning/Management stage
(predicting the future)
Input
Output
Compare

# Additional Uncertainty

- Transboundary Uncertainty
  - Decision Uncertainty
    - Implicit Decisions
    - Ambiguities in Social Objectives
  - Linguistic Uncertainty
    - Miscommunication
    - Missing Networks

# Uncertainty Estimates

- Empirical – Chebyschev Inequalities
- OME – Factor of 3-5
- Dynamic Methodology
  - Latin Hypercube
  - RSA
  - GLUE,
  - IBUNE
  - Ensemble
  - Etc.

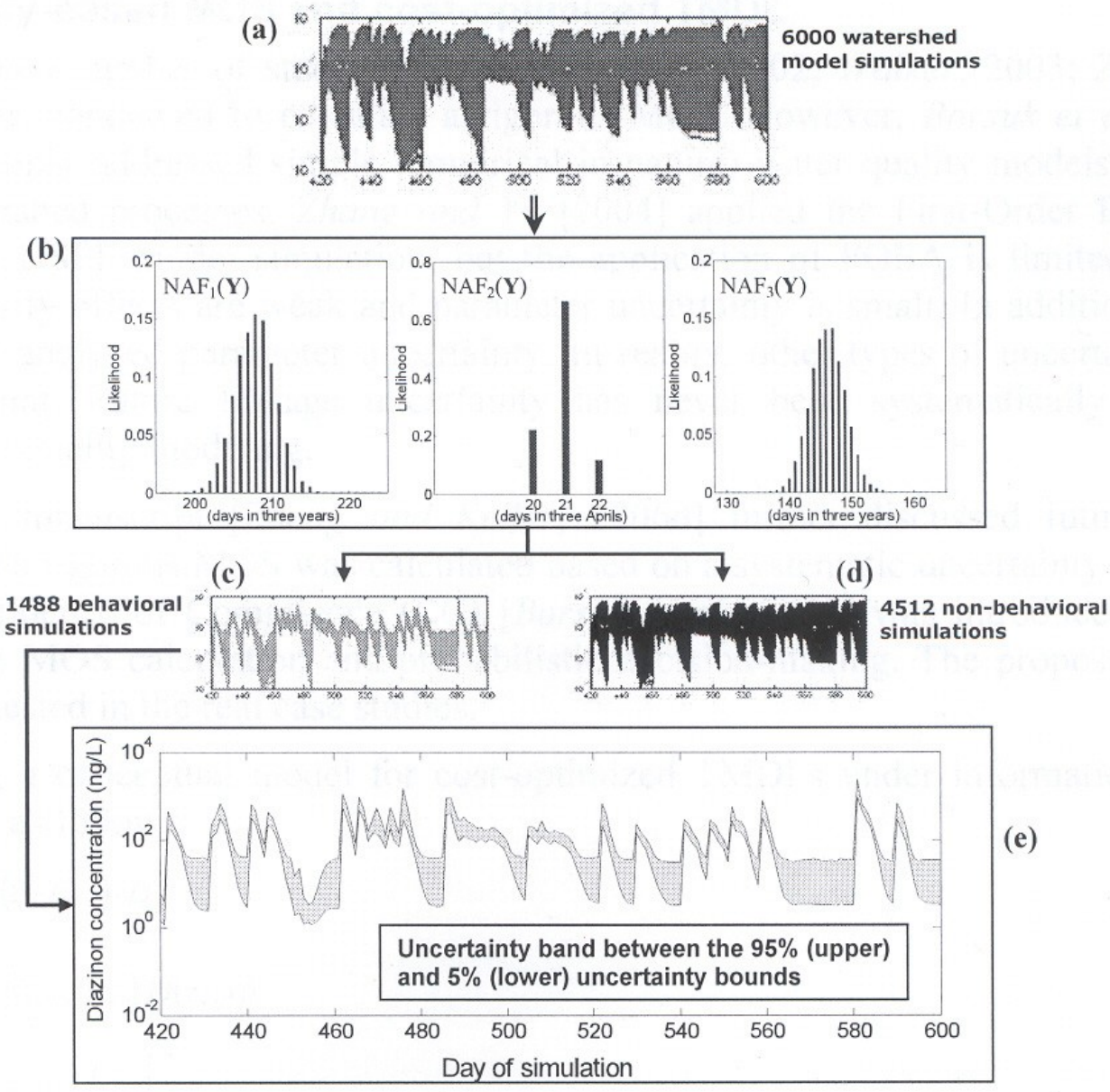
# Uncertainty Estimates

- Ensemble Modeling
  - Uses Multiple Models (Tools)
  - Incorporates Several Uncertainty Sources
  - Provides General Likelihood Estimators
  - Potential for DSS

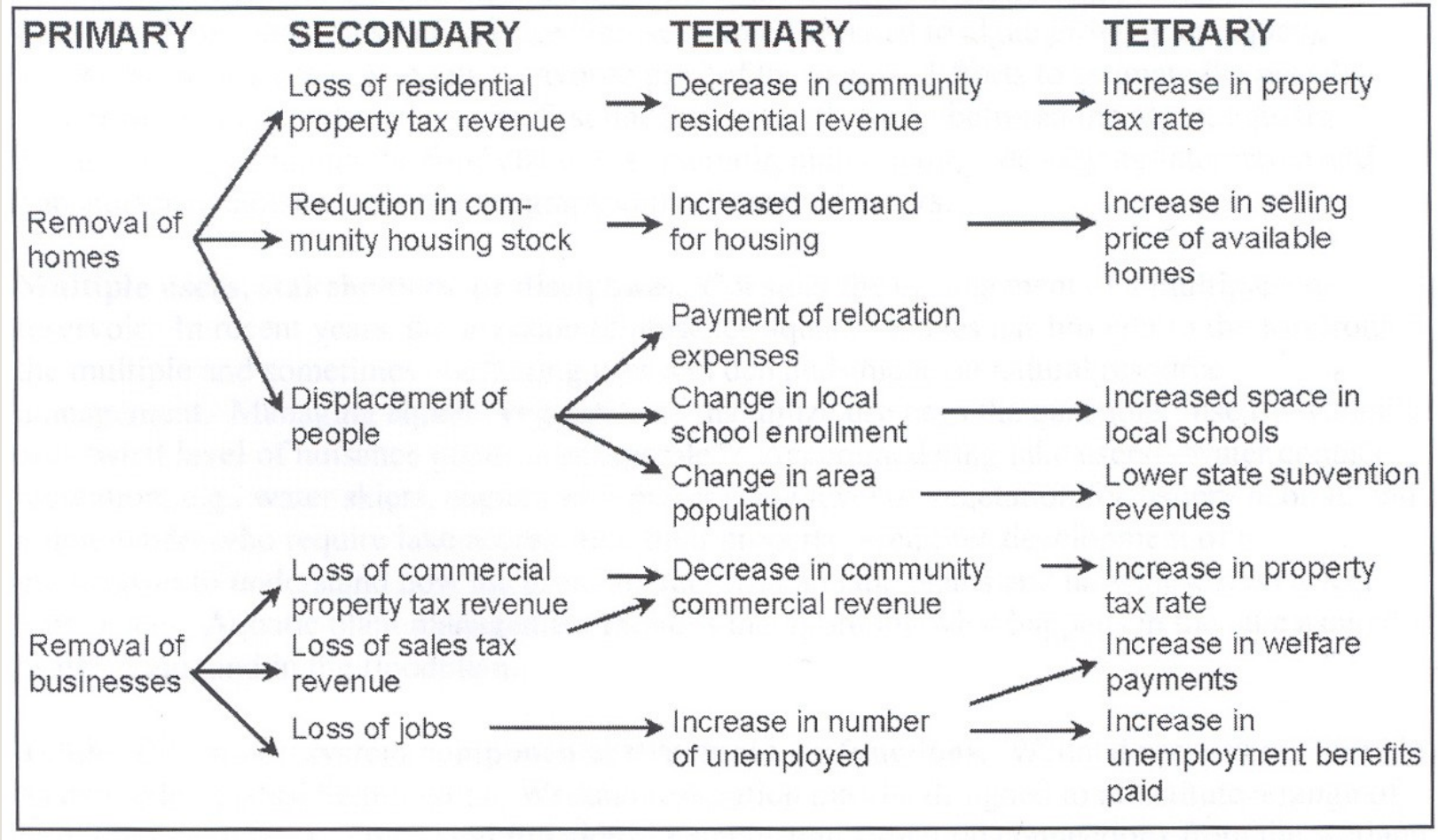
# Uncertainty Estimates

- Alternative Approaches
  - SEM or Path Analysis,
  - Analytic Hierarchy Process
  - Fuzzy Logic
  - Multi-attribute Utility Functions
  - Delphi, Elicited Estimates
  - Neural Networks, Genetic Algorithms
  - Cellular Automata

# Mgt. Obj. Const. Anal. Uncertainty



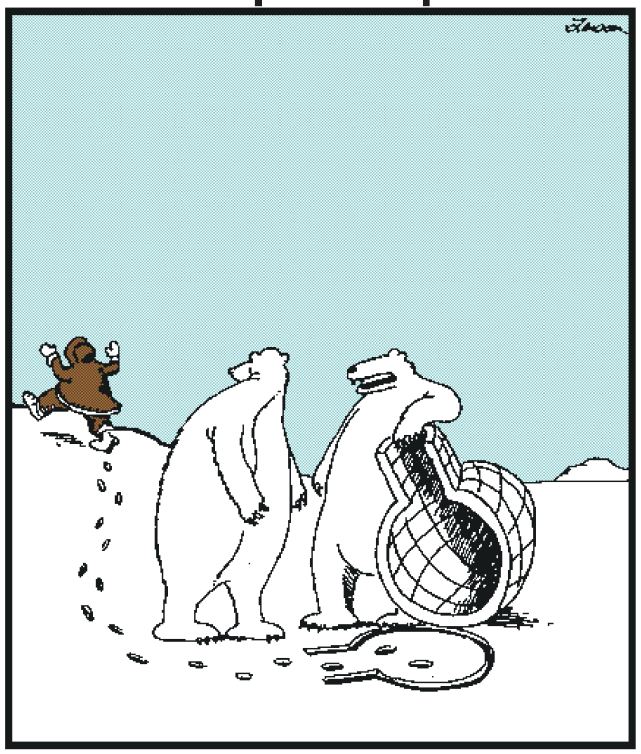
# Monte Carlo Markov Chain (MCMC)


PRIMARY
SECONDARY
TERTIARY
TETRARY
Removal of homes
Loss of residential property tax revenue
Decrease in community residential revenue
Increase in property tax rate
Reduction in community housing stock
Increased demand for housing
Increase in selling price of available homes
Displacement of people
Payment of relocation expenses
Change in local school enrollment
Increased space in local schools
Change in area population
Lower state subvention revenues
Removal of businesses
Loss of commercial property tax revenue
Decrease in community commercial revenue
Increase in property tax rate
Loss of sales tax revenue
Increase in welfare payments
Loss of jobs
Increase in number of unemployed
Increase in unemployment benefits paid

# Communication

- Marketing Mentality
  - Stay On Message
  - Keep It Simple (KISIS)
  - Single Message
  - Do Not Send Mixed Messages
  - Trusted Source for the Message
  - WIIFM

Keep It Simple



"I lift, you grab. ... Was that concept just a little too complex, Carl?

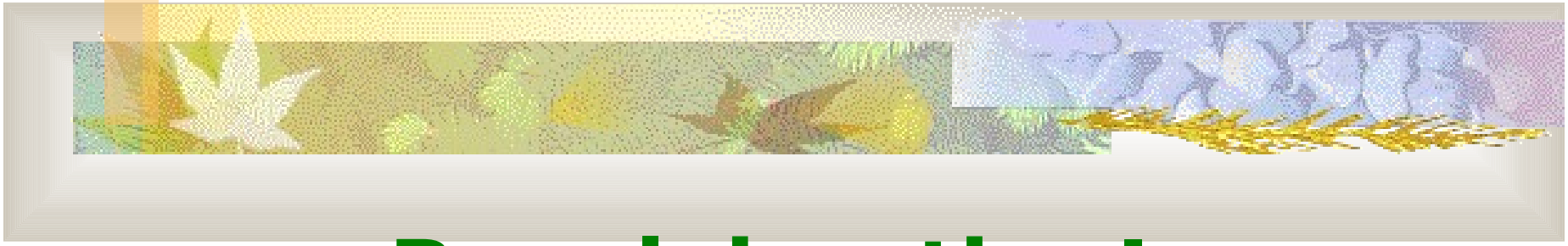
# Communication

- Military Briefing
  - Approach
    - Tell Them What You Are Going To Tell Them
    - Tell Them
    - Tell Them What You Told Them
  - 3 - 6 x Rule
  - Tell Them Again

# Messages

- Use Weight of Evidence Approaches
- Provide Risk or Uncertainty (Certainty) Estimates
- Tailor the Message to the Audience

# Integrated Process



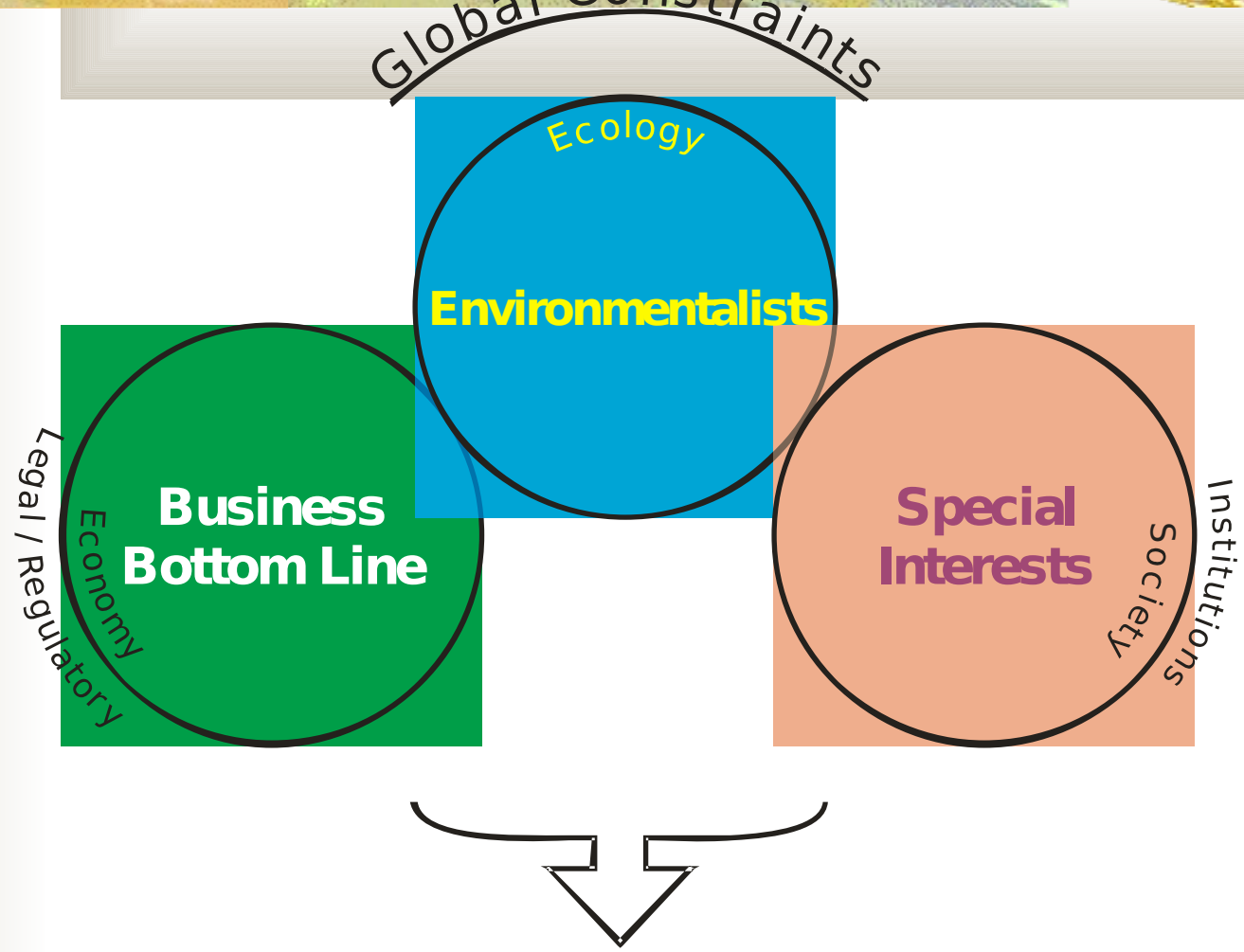
## Resolving the Issue

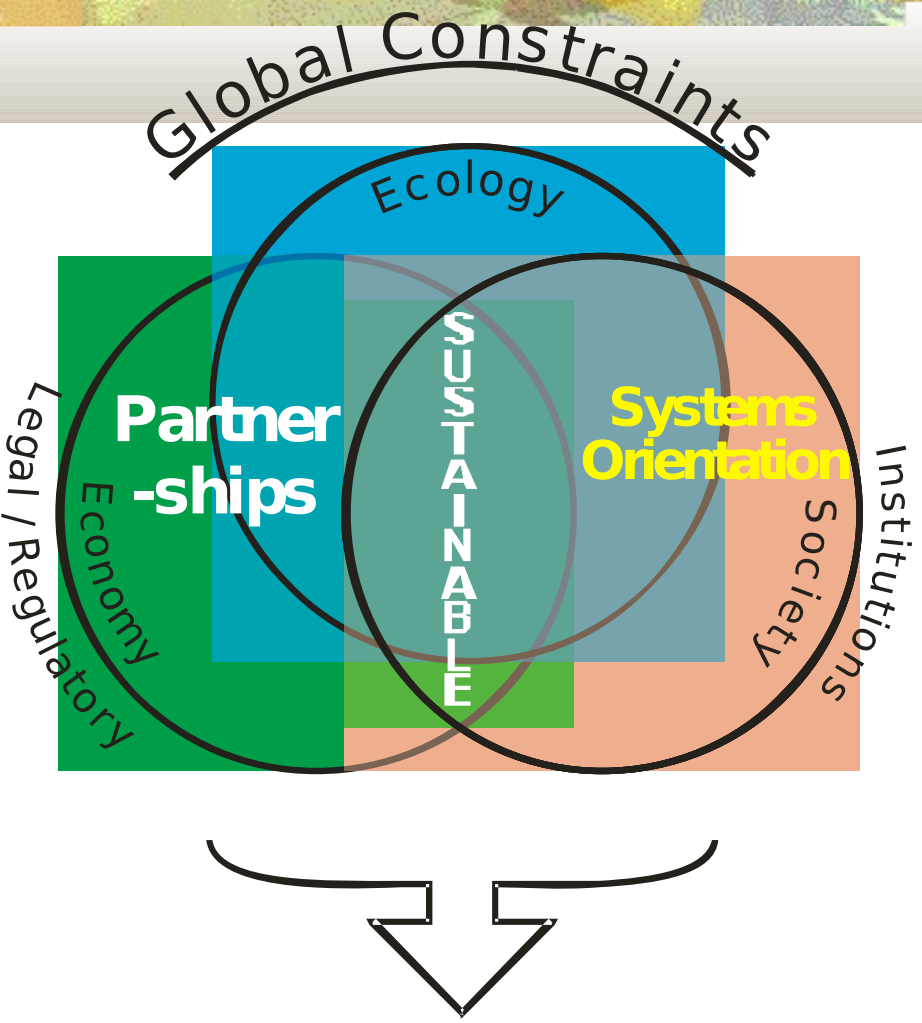
# Messages

- Engineering Solutions Necessary, But Not Sufficient
- Socioeconomic Perspective Provides Better Problem Solutions and Issue Resolution
- Objective – Contribute to Decisions

# Issue Resolution

- Integrating Socioeconomic and Environmental/Engineering Approaches
  - Economic
  - Psychometric
  - Sociological Methods

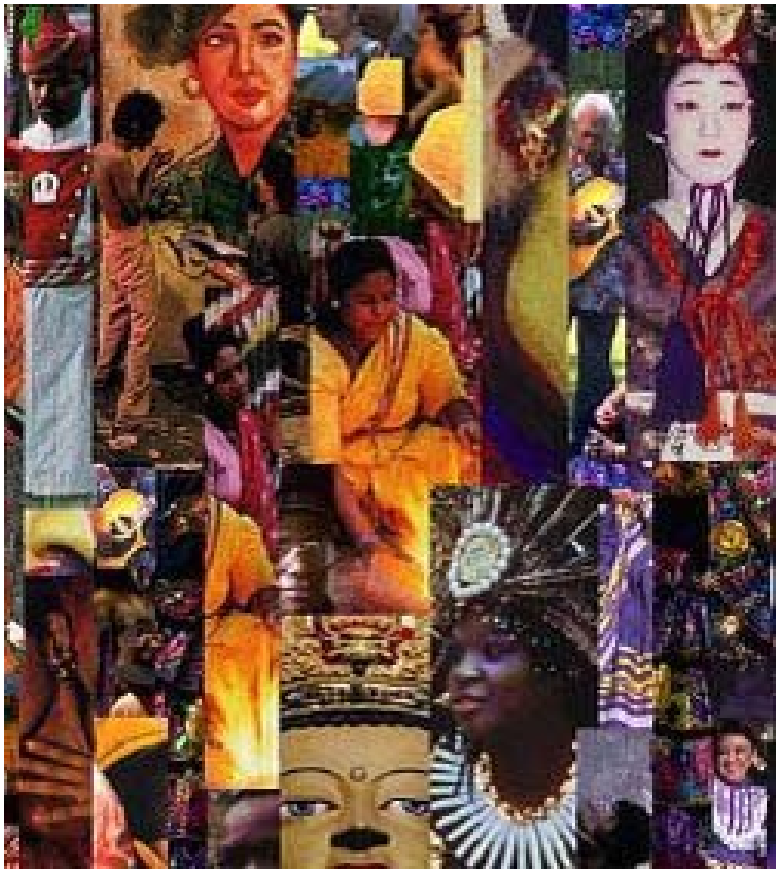

Global Constraints
Ecology
Environmentalists
Business
Bottom Line
Economy
Legal / Regulatory
Special
Interests
Society
Institutions
Unsustainable
Management




Sustainable
Management

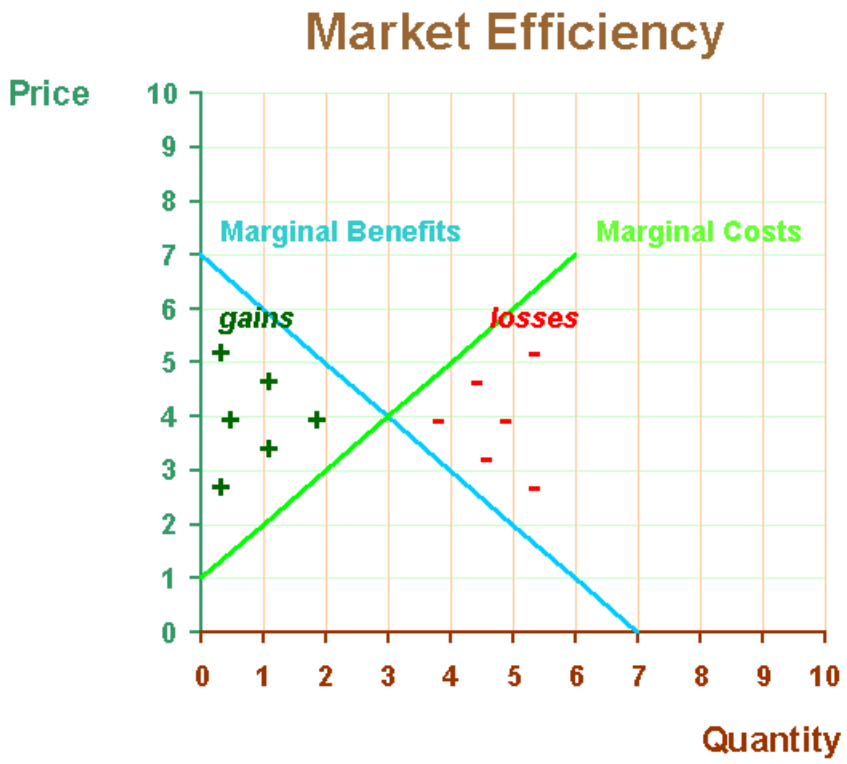
# Social/Cultural

- Beliefs & Values
- Social Networking
  - Influencers
  - Networks
- Social Marketing
  - Public Awareness
  - Behavioral Mod.



# Economy

- Valuation
  - Market-based
  - Non-market based
  - Ecosystem Services
- Full Cost, Full Value

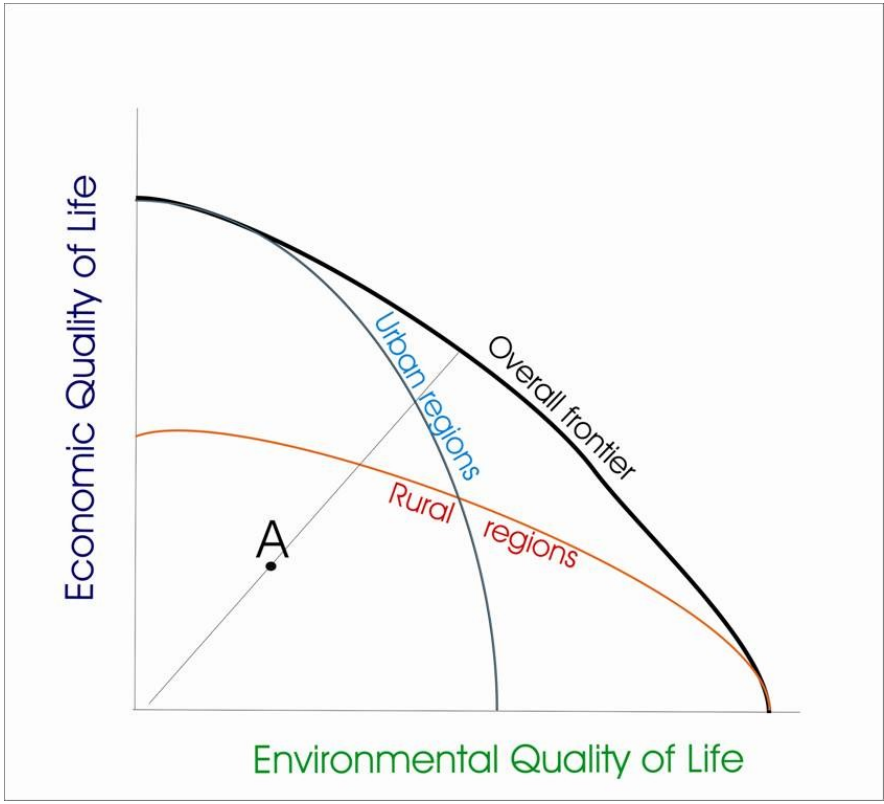


# Ecosystem Services

- Provisioning
  - Food
  - Fresh water
  - Fiber and Wood
  - Fuel, etc.
- Regulation
  - Climate
  - Flood
  - Disease
  - Water Purification
- Cultural
  - Aesthetics
  - Spiritual
  - Recreational
  - Educational
- Supporting
  - Water Cycling
    Nutrient Cycling
  - Soil Formation
  - Primary Prod

# Frontier Analysis

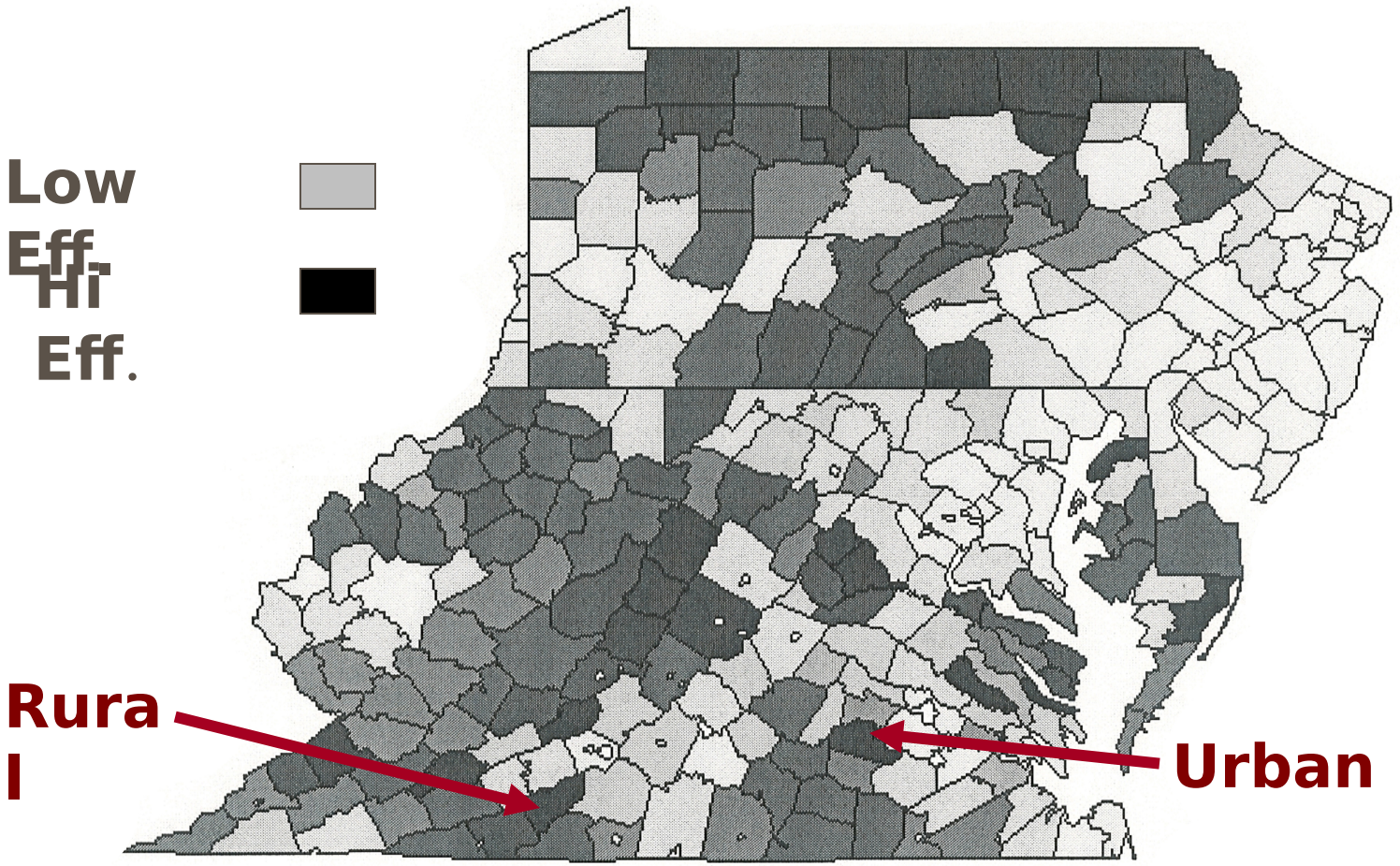
- Production Efficiency
- Comparative Basis
- Compare
  - Environmental indicators
  - Social indicators
  - Economic indicators



# Indicators (Input, Output)

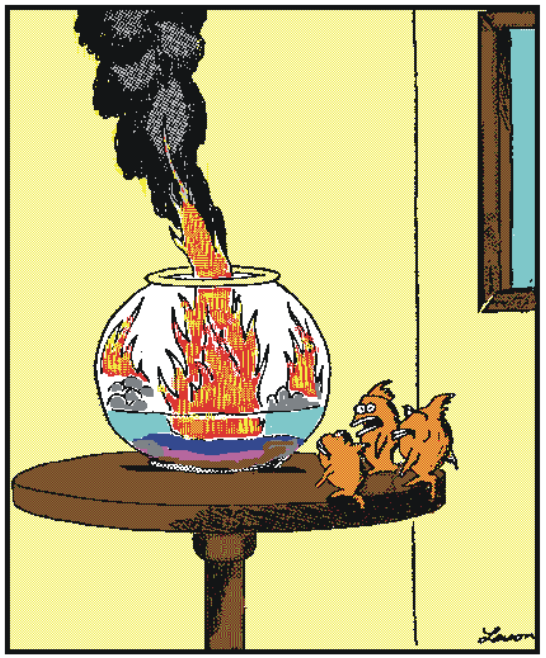
- Input
  - EPA's Cancer Risk Index
  - % Developed Land
  - Teacher/Pupil Ratio
  - % HS Grads
  - % Pop < Poverty Income
- Output
  - No. Arts, Rec., Entertainment Establish./$mi^2$
  - Median House. Income
  - Amenity Index

# VEA – Comparative Basis



# Unintended Consequences

- What You Don't Know Can Hurt You!
- Need Multiple Perspectives and Inputs
- Integrated Process and Adaptive Mgt.



Whew! Made it out just in time.
Of course, we're equally screwed now!

# Messages

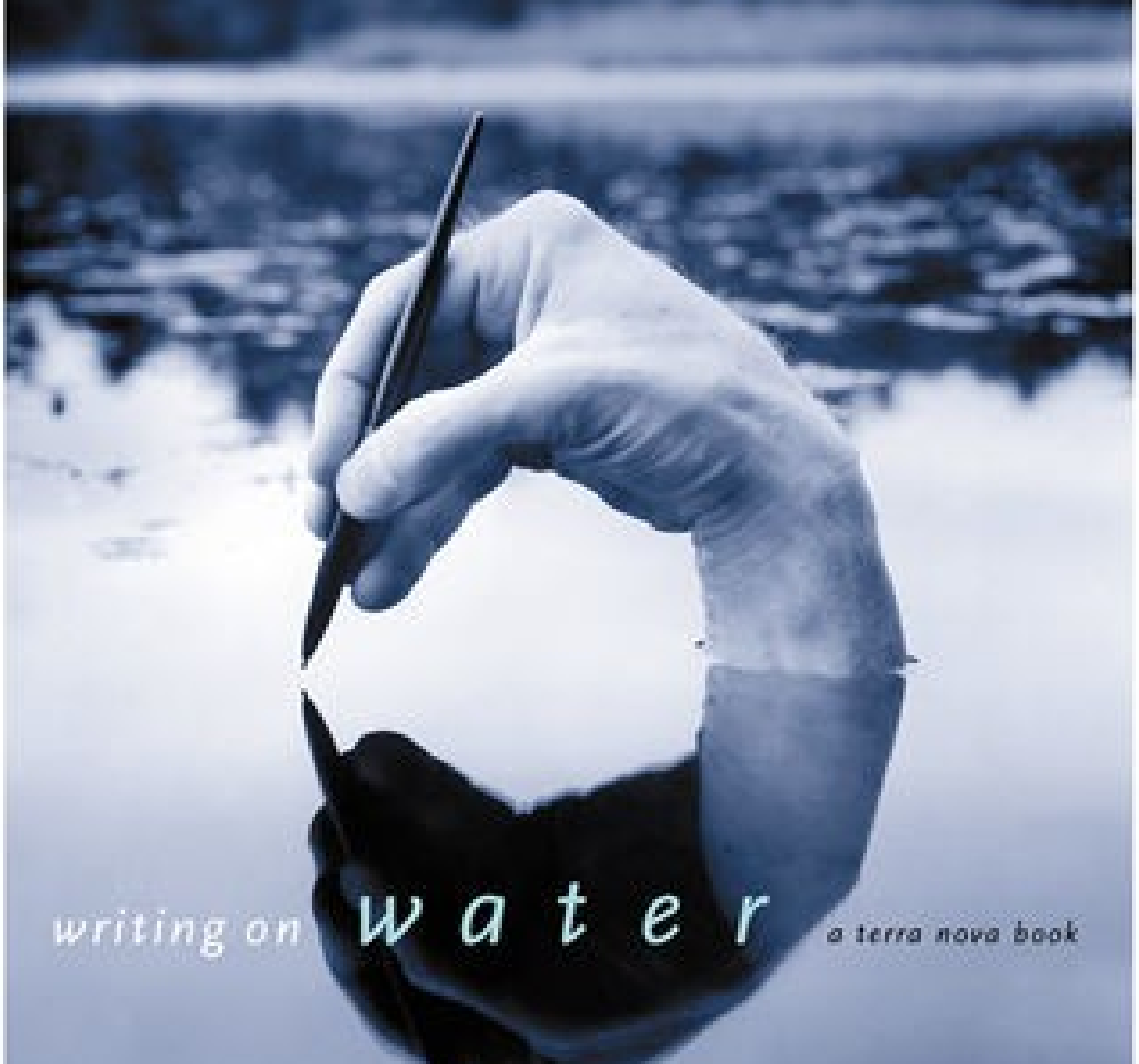
- Engineering Solutions Necessary, But Not Sufficient
- Socioeconomic Perspective Provides Better Problem Solutions and Issue Resolution
- Objective – Contribute to Decisions

# Bottom Line

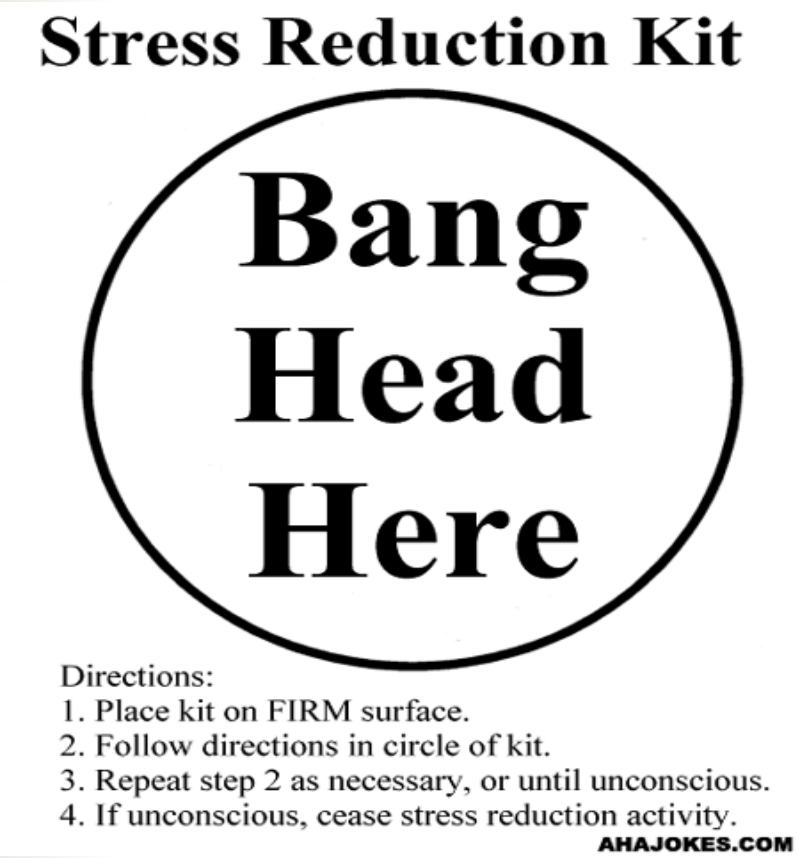
- **It's the Whole;**
  **Not the Parts**
- **It's the Process;**
  **Not the Product**
- **It's the Issue;**
  **Not the Problem**

# Questions ?

# Discussion


writing on water
a terra nova book

# Eliminating Frustration


Stress Reduction Kit
Bang Head Here
Directions:
1. Place kit on FIRM surface.
2. Follow directions in circle of kit.
3. Repeat step 2 as necessary, or until unconscious.
4. If unconscious, cease stress reduction activity.
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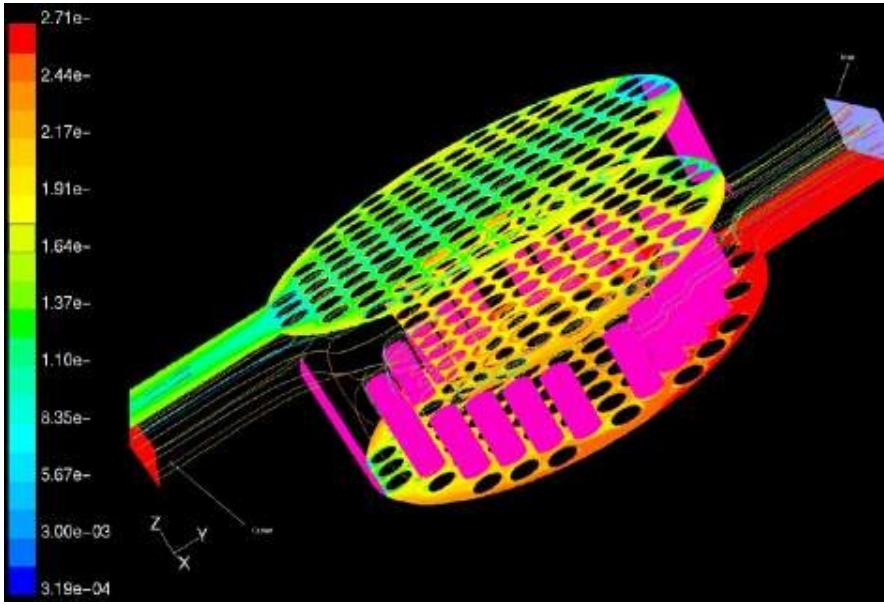
- Why Do Some Solutions Take and Others Don't?
- What Makes The Difference?
- Is Banging My Head Against This Wall The Only Way?

# Why Won't Anyone Listen?

- Great Technical Solutions
  - Heterogeneous Photovoltaic/Fuel Cell for WWTP
  - Tidal Hydropower Generation
  - Conservation Tillage, Nutrient Probes



Missouri
Upper Mississippi
Ohio
Arkansas-Red-White
Tennessee
Lower Mississippi
Hypoxic Zone
Gulf of Mexico